TROPICAL FOREST DEPLETION ASSESSING THE FOREST PRODUCTS TRADE AND ECONOMIC INFLUENCES ON THE FOREST AREA INDUSTRIALLY LOGGED

By

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This dissertation is dedicated to my mother Merna Woollery whose strength of character enables her to trust in the values she instills in her children and guide us along the morally correct path

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Abstract of Dissertation Presented to the Graduate School
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TROPICAL FOREST DEPLETION: ASSESSING
THE FOREST PRODUCTS TRADE AND ECONOMIC
INFLUENCES ON THE FOREST AREA INDUSTRIALLY LOGGED

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Motivated by the assumption that commercial logging catalyzes the deforestation process, the trade in forest products, foreign assets, and stress from foreign debt are evaluated for depleting influences on tropical forest stocks. A conceptual optimal control model incorporating an endogenous forest clearing function, foreign capital, and a unique measure of financial distress is solved to evaluate influences on tropical deforestation. The results underscore the importance of foreign capital, foreign debt, and the forest product trade in conditionally depleting forest stock.

A simultaneous equation time series model, conditioned on estimation of an index of financial distress from foreign debt, is developed to assess forest product

trade and economic influences on the forest area industrially logged The model is estimated for Ghana over 1967 1994 The FS index accounts for four different determinants of financial distress profitability import availability debt ratio and the debt service ratio It is introduced in the simultaneous forest clearing model as a shifter via the income effect.

The empirical results support the hypothesis that the international trade in forest products has depleting influences on Ghanaian forest area industrially logged Moreover the marginal influence of total foreign reserves on the forest area cleared is positive indicating a role for traded forest goods in generating foreign capital Ghanaian domestic policy reform real exchange rate depreciation and relative wood price increase pressure on commercial forest area while a ban on log exports reduces pressure on forest stock Surprisingly increasing distress from foreign debt appears to reduce pressure on Ghana's forest stock however the significance of the associated negative sign is minimized due to an exceedingly small elasticity of forest area industrially logged with respect to financial distress

The implications of the research are i) foreign capital is needed to finance economic progress ii) unless other resource-using economic alternatives are found tropical forest countries will continue to liquidate forest resources to generate foreign capital and iii) the global public good nature of tropical forests is endangered if alternative sources of capital financing are scarce

CHAPTER 1
INTRODUCTION

In the End
we will conserve only what we love
we will love only what we understand
we will understand only what we are taught.

Baba Dioum

Tropical Deforestation: The Issue

The global community's interest in the quality of the earth s environment and the status and health of its stock of natural resources has taken on increasing concern in recent years. Our collective concern is manifest via global treaties and programs to protect and conserve the earth s environment, wildlife, and natural resources. Furthermore, environment summits such as the Earth Summit in Rio de Janeiro, June 1992, and the Bolivia Hemispheric Summit Conference on Sustainable Development, December 1996, demonstrate proactive steps aimed at coming to terms with earth s environmental dilemmas. Included among the global community s resource concerns is the status and condition of the world s forest stock, and the implications of forest stock loss for human welfare. The 1980 'Global 2000' report to President Jimmy Carter of the United States identified tropical deforestation as the most serious environmental problem that the world

would face in the n nelies end into the third millennium (U S Interagency Task Force on Trop cal Forests 1980)

The extant forest performs a wide range of valuable ecological and social services Ecological services performed include the following its role as a global store of carbon which if released in excessive quantities in the form of carbon dioxide contributes to global warming its vital part in retaining soil and soil nutrients essential for agricultural productivity and its service as the world's greatest storehouses of biological diversity significant contributors to modern medicine agriculture and industry (Burgess 1995) Social services performed include its provision of living quarters and sustenance for upward of four hundred million people globally (Johnson and Cabarle 1993) and its role in providing perenn al water supplies and ability to reduce the incidence of severe flooding landslides and sedimentation The disappearance of humid tropical forests corresponds to loss of these essential services

As of 1993 forests were disappearing at a count of approximately 17 million hectares per year (Johnson and Cabarle 1993) Between the periods 1976-1980 and 1981-1990 world deforestation rates increased twofold from 0 6% per year to 1 2% per year (Amelung, 1993) Regionally Africa experienced the greatest increase n forest loss (0 5% per year to 1 7% per year) followed by Asia (0 6% per year to 1 4% per year) Latin America experienced the least increase in rate of loss in forest stock over the two periods (0 7% per year to 0 9% per year)

Tropical deforestation is a complex problem spanning many facets of human behavior. Activities such as industrial logging for timber exports and domestic consumption, land clearing for commercial agriculture to serve domestic and export markets, small scale agriculture by financially limited shifting cultivators, and increased population pressures impose negative effects on the forest ecological system, and ultimately contribute to the process of deforestation. Although these human activities contribute to the direct cause of deforestation, government policies condition the opportunity set available for human use. Consequently, policy externalities from government policies contribute to deforestation through economic actors conducting daily activities. For example, Maher (1989) and Binswanger (1989) illustrate different ways in which inefficient government policies cause deforestation. Given the many dimensions of the problem, it is no surprise that analysis of the root causes of tropical forest depletion is difficult.

Commercial logging and the timber trade have been tagged a major indirect cause of tropical deforestation (Amelung and Diehl 1992, Barbier et al. 1991) and therefore a major global policy concern. Consequently, timber management is among the most controversial issues in the international debate over tropical deforestation. In response to increasing concerns about the role of the timber trade in driving tropical deforestation and faced with great uncertainty about the feasibility of sustainable timber production, the World Bank, USAID, and other donor agencies now craft policies which eschew financing projects involving commercial logging in primary forests. In light of many developing countries' needs for foreign capital to

finance economic growth and meet external financial obligations some observers fear that these highly principled decisions could quash economic incentives to innovate methods to harvest timber and other natural forest resources sustainably Consequently the destruction caused by timber mining could become worse

The relationship between foreign capital availability foreign debt and the timber trade has not been explored with reference to tropical deforestation This is surprising g ven the importance of foreign capital to the growth and development process of tropical countries Sources of foreign capital include international sale of primary resources loans from international lending organizations grants in aid remittances and interest from investments abroad as well as marketing of some final products. Generation of foreign capital from the sale of primary resources can be unduly costly if the rate of extraction exceeds the rate of regeneration Environmental problems tend to arise in these cases All loans are eventually due and the cost of default is usually decreased access to future loans at favorable interest rates and very light conditionalities Grants are best since they are 'free' however as a consistent source of funds they are unreliable since grants are a function of international goodwill Remittances and interest earned from investments abroad are theoretically great sources of foreign funds but historically they have not proven to be lucrative And typically these developing countries have little competitive edge in international financial markets Therefore developing

countries are left with two sources of foreign funds the liquidation and sale of primary resources or dependence on international loans

The issue is especially topical since in some cases logging for timber export revenue catalyzes the deforestation process (Johnson and Cabarle 1993 p 15) This process can be perceived as a three stage pattern First the forest is opened by the construction of access roads to facilitate commercial logging This initial encroachment opens the forest to locals who continue the process of transforming the forest Pfaff (1996) demonstrated this effect in the case of the Brazilian Amazon The third stage involves complete forest destruction The forest area is transformed into land for commercial and subsistence agriculture housing development and cattle rearing to name a few which are deemed potentially more valuable than the erstwhile existing forest. Lanly (1982) estimates that deforestation rates are eight times greater in closed tropical forests selectively logged than in undisturbed (virgin) closed forests

In the face of immense macroeconomic problems and the burden of debt some governments have little alternative to opening their forests for commercial exploitation to generate foreign capital and ease macroeconomic burdens (Jagan 1996) Therefore the health of the environment is sacrificed for the immediate need for foreign capital requirements to meet current economic objectives

The primacy of commercial logging in opening the forest is thus underscored The compelling issue becomes one of establishing the relationship between foreign

capital availability foreign debt stress forest product trade and tropical forest depletion Previous research with few exception (Capistrano and Kiker 1995 Kahn and McDonald 1995) have avoided macro-economic and financial considerations Where consideration is rendered the focus is typically on the role of total external debt in influencing the deforestation process The current work builds on previous research by examining a partial component of the deforestation process the forest area industrially logged Within this context it examines the link between the timber trade foreign capital availability, stress from foreign debt and tropical forest depletion

Problem Focus for the Study

The impacts of human behavior on tropical forest environments occur as a result of the need for capital to alleviate poverty invest in productive inputs increase consumption and relieve stresses from external financial obligations Tropical countries in the aggregate account for roughly one-third of the world's forest cover These forest systems contain at least half of the world s biological species, provide invaluable eco-system services regulate local and global climate and are providers of homes and nutritional sustenance to upward of four hundred million people Consequently loss of tropical forest stocks entails welfare impacts which transcend tropical country borders and impose negative externalities globally

Tropical deforestation rates continue to increase locally, regionally, and globally, without respite. From an economic perspective it is not clear what effect forest product export revenue, foreign capital availability, and stress from foreign loans have on the transformation of tropical country forest environments. Possible effects include an increase in the area industrially logged, due to greater forest product export revenue rising forest product prices, increasing distress from foreign debt, and decreasing stocks of foreign reserves. Improved comprehension of these effects is essential for development of policies that could be beneficial for individual tropical forest countries and the developed world. These policy effects are of course all relative to the conservation and preservation of tropical country and global forest stocks. There is no single measure for a country's financial distress from foreign debt, but only different measures that provide an idea of the different components of this distress. The sundry components must be integrated into a single reliable measure to determine the degree to which a country experiences distress from foreign debt. Subsequently such a measure will aid in assessing the relative influence of foreign debt on tropical forest depletion in individual tropical countries.

Objectives

The general objective of the study is to determine the effects of foreign capital needs on tropical forest depletion. Specific objectives are to

1 Develop a conceptual economic model to assess the relationship between forest product trade, foreign capital availability, and financial distress from foreign debt on the industrially logged forest area.

2 Construct an index for assessing the temporal distribution of financial distress for Ghana which takes into account short-term foreign exchange availability and debt repayment problems (cash flow or debt service) vis-a vis long term profitability and financial insolvency problems.

3 Develop an empirical model to assess the effects of the forest products trade on wood production and the industrially logged forest area. Additionally, the model will assess the effects of foreign capital availability and increasing financial distress from foreign debt on the industrially logged forest area;

4 Identify the economic relationship between financial distress and tropical forest depletion, specifically the industrially logged forest area.

5 Establish the effect of Ghanaian financial distress from foreign debt on Ghanaian tropical forest depletion.

6 Underscore the policy implications of the empirical findings for tropical forest policy aimed at mitigating the increased incidence of tropical deforestation. This information could be of use to the World

Bank, the Tropical Forest Action Programme (TFAP) and other actors shaping the new tropical forestry policy agenda

Procedures

The conceptual model follows the optimal control framework developed by Rauscher (1990) and Barbier and Rauscher (1994). To derive effects on the forest area industrially logged, the industrially cleared forest area is modeled as an endogenous variable.

Empirical estimates are derived from a simultaneous equation system using three stage least squares. Additionally, system marginal effects will be calculated to evaluate the effect of individual variables on the industrially logged forest area. These marginal effects are then used to compute system elasticities which will facilitate comparison of the variables' effects on the industrially logged forest area.

Data covering 1967 - 1994 are collected from various secondary sources. These include publications of the World Bank, International Monetary Fund, and the Food and Agriculture Organization.

Overview of the Dissertation

The organization of the dissertation is as follows. Chapter 2 introduces the reader to a definition of the process of deforestation. It discusses scales, trends, and agents of forest cover loss. Chapter 3 is a discussion of the economics of

deforestation Chapter 4 develops the conceptual economic model used to characterize the relationship between forest product trade foreign capital availability and financial distress on the forest area industrially logged Chapter 5 introduces the reader to the dissertation s case study Ghana Chapter 6 presents the empirical model developed to assess the relationship between Ghanaian forest product trade foreign capital availability and financial distress on the forest area industrially logged Chapter 7 identifies data sources and data definitions Chapter 8 presents empirical results and discusses the meaning of the empirical results Chapter 9 closes the dissertation with conclusions, policy implications and forwards recommendations for future research

CHAPTER 2
CHARACTERIZING LAND COVER CHANGE

This chapter characterizes and geographically demarcates the resource of concern. Ecological concepts used to classify forests and terminology germane to research on forest cover loss are identified and defined. A brief sketch of trends in forest cover loss followed by a description of the main agents of forest cover loss gives a feel for temporal and spatial changes in the geography of tropical forest areas and the main instigators of these changes.

Tropical Forests

Geographically tropical forests are located 23.5° north and south of the equator, are found in more than 80 countries and account for one-third of the world's forest cover (WRI 1992 cited in Johnson and Cabarle 1993, p.5). Forests can be defined as a biological community characterized by closed canopy in the tree stratum and a sparse herbaceous layer with a few grasses (Deshmukh 1986). They are dynamic, interactive and self-perpetuating communities of living organisms in which trees dominate the vegetation and interact closely with each other and their physical environment (Johnson and Cabarle 1993).

Tropical forests can be divided into two categories *Humid Tropical Forests* and *Tropical Dry Forests* Humid tropical closed forests are composed of natural forests characterized as "moist forest" "wet forest" and "rain forest" while tropical dry forests are composed of vegetation characterized as "dry forest" and "very dry forest" (Johnson & Cabarle 1993 p 6) Humid tropical forests cover approximately 8 million square kilometers while dry tropical forests and woodlands cover approximately 10 million square kilometers (Myers 1989 cited in Johnson and Cabarle 1993)

Ecologically tropical forests are defined to be located in biomes[1] unique to the tropics When making comparisons across geographical regions the biome concept is the most preferred characterization scheme since forests are more similar physiognomically and in community attributes such as diversity or energy flow than are rain forests and nearby savannas on the same continent (Deshmukh 1986) For these reasons the study employs the biome concept to characterize the tropics rather than the latitudinal definition

Definitions and Scales of Forest Cover Loss

The process of land cover change as it relates to tropical forests is best conceptualized in two facets The first provides definitions of the different degrees of land cover change and the second puts to use these definitions to ascribe

[1]Biomes simply refers to the subdivision of world vegetation into recognizable physiognomical categories the distribution of which is governed primarily by global climatic patterns (Deshmukh 1986 p 181)

drivers of land cover change specifically deforestation in the tropics In defining the various elements of land cover change a gradated scale is utilized to demonstrate the process of change from fully forested land to relatively treeless land

Before a scale is developed the concepts of primary and secondary forests must be defined

> Primary forest is defined as an ecosystem characterized by an abundance of mature trees which has been relatively undisturbed by human factors Such forests have had human impacts restricted to low levels of artisanal hunting and fishing and harvesting of forest products and in some cases to low density migratory shifting agriculture and selective cutting of a few tree species Included in this definition are forests called virgin (no disturbance) primary and climax and
> secondary forests are regenerating from a substantial disturbance (fire or flood land clearing or extensive lumbering) they have relatively few mature trees and are generally characterized by an abundance of fast-growing species and a thick understory of saplings herbaceous plants and 'weedy' forms Although secondary moist forests tend to peak in terms of biomass after about 15 years regeneration back to prime forest is a much longer process (75 years to 100 years) and depends on the intensity of the initial disturbance Irreversible transformation of the underlying soil and nutrient cycle brought about by chronic or intense land use may prevent the return of the original primary forest (Savage 1988 p 5)

The process of land cover change affects primary and secondary forests and these effects can be classified along a continuum. The forest continuum goes from fully forested land (primary forests) through degraded forest land with some regeneration (secondary forests) to fully deforested land (grassland) Essential

features and definition of these features (terms[2]) along the continuum are now articulated

Forested land This is associated with virgin forest, the primary forest undisturbed

Degradation A vague concept to define degradation is usually couched in terms of *forest modification* and *biomass reduction*. *Forest modification* is an economic sectoral share measure It assesses sectoral contributions to the conversion of primary forests into productive closed forests or other forms of land use that engenders ecological damages and therefore compromise the regenerative capacity of the forest ecosystem (Amelung & Diehl 1992) Forest modification is important because it recognizes that various economic activities can open up primary forests for other economic sectors by lowering the cost of access to successive users of tropical forest resources

Biomass reduction is a measure which assesses the ecological and economic damages incurred by the forest as a result of economic intrusions This assessment quantifies the reduction in weight per unit area of production of forest organic matter temporally Biomass reduction is important because it recognizes the sensitivity of the forest ecosystem to variegated human activities These activities cause potential disturbances to primary and secondary forests which can adversely change the forest ecosystem relationships and functions therefore reducing the viability of the forest environment.

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[2]These definitions follow those of Lanly (1982) and Amelung and Diehl (1992)

Taken together *forest modification* and *biomass reduction* define forest degradation to mean any disturbance to the forest stand that changes the initial character of the forest ecological system such that it is no longer in the primary forest classification.

Depletion This is defined to mean a definite reduction in canopy/forest cover. It encompasses forest degradation but is farther along the continuum because trees disappear at this point but parts of the initial forest remain.

Deforestation The concept is defined to mean the total removal or clearing of forests and biomass resulting in the transformation of land cover from fully forested land to forestless land: grassland or savannah. Sometimes a distinction is made between *strict deforestation* and *general deforestation*. *Strict deforestation* refers to forest clearing without regard to degradation. *General deforestation* refers to areas strictly deforested plus areas degraded. The difference in definition affects estimates of deforestation at all levels.

Trends in Forest Cover Loss

Where We Were: Pre-1970

In the period leading up to 1970 there was relatively little concern for deforestation or issues thereof. This was the case not because forests were not being depleted or disturbed[3] but because deforestation was not perceived to be

[3]See Mahar (1989), Kelly (1980), and Williams (1989) for further details on pre-modern depletion of forest stock.

occurring at an alarming rate It is important to note that during this period forested lands were not a part of the national economic frontier in many countries because the state of technology did not facilitate access at low cost. Therefore forests were mainly used for subsistence purposes and these activities did not compromise the regenerative capacity of the forest ecosystem

Where We Are: Post 1970 to Present

The early seventies witnessed the first attempts to assess changes in forest cover One such venture was the American federal government s Radar in Amazon a Project (RADAM) which employed airborne side-looking radar to gather primary data to generate scientific estimates of deforestation in legal Amazonia (Meher 1989) Initial estimates indicated no reason for alarm However a few years later landsat satellite images provided more comprehensive estimates of deforestation which revealed that as of 1975 roughly 30 000 square kilometers or about 0 8 percent of Amazonia (and approximately 1 0 percent of the forest) had been cleared (Meher 1989) These estimates continue to rise today

There have been several assessments of the global forest inventory and deforestation rates (FAO/UNEP 1982 Myers 1991) Although many of these exercises differ in findings there is conformity in conclusions concerning the demise of forest stocks The Food and Agriculture Organization (FAO) and the United Nations Environment Program (UNEP) global assessments report that tropical forests formerly covered 14 5 million square kilometers (Sommer 1976)

however the amount remaining as of the late 1980s was approximately 7 5 million square kilometers (Myers 1989)

Up to 1979 tropical moist forests had lost approximately 75 000 square kilometers of their expanse and by 1989 deforestation had been estimated at 142 000 square kilometers(Myers 1980) Therefore over the ten year period 1979-1989 the increase in deforestation was 89% Extrapolation of these data projects absolute global deforestation in 1991 to be in the area of 146 000 square kilometers which corresponds to an annual rate of 1 97% of total forest remaining (Myers 1993)

The foregoing gave indicators of global deforestation however it is important to note that deforestation patterns and trends are not homogenous across countries regions, and the ecobiome. Average annual deforestation rates for the 1976-80 period and the 1981-90 period for three regions, Africa Latin America and Asia & Oceania are presented in Table 2 1 The figures indicate that deforestation rates differ across regions and over time. Regional rates of deforestation have increased and become more dispersed Africa exhibited the highest average annual deforestation rate and experienced the greatest increase in average annual deforestation between the two periods (over three times the 1976-80 rate) followed by Asia & Oceania (over two times the 1976-80 rate) and Latin America (much less than a one-fold increase over the 1976-80 rate) Therefore the evidence suggests that perceptions of a tropical deforestation problem in the early seventies were not only real but confirmed by ex post scientific studies

Table 2 1-- Results of the 1980 and 1990 FAO/UNEP Tropical Forest Resources Assessment Projects

	Average Annual Deforestation 1976-80 (in%)	Average Annual Deforestation 1981 90 (in%)
West and Central Africa (15 countries)	0 5%	1 7%
Latin America (22 countries)	0 7%	0 9%
Asia & Oceania (15 countries)	0 6%	1 4%
Total	0 6%	1 2%

Source T Amelung (1993)

Presently, several regions and various countries are experiencing excessive rates of deforestation Myers (1993) identifies 14 areas termed deforestation fronts[4] which feature mainly primary forests together with some extensive tracts of secondary forests These areas account for 25% of all tropical moist forests, 43% of all deforestation and are in critical condition because they engender annual rates of deforestation at or exceeding 3% Therefore individually they are unhealthily out-pacing the ecobiome-wide rate of 2% (see table 2 2)

Equally important is the list of good news areas which do not presently have significant deforestation underway today or likely in the foreseeable future These areas include Venezuela Guyana, Surinam, French Guiana Gabon Congo Zaire, and Papua New Guinea In the aggregate their forest tracts account for 2 4

[4]These are areas that feature the most intensive widespread and rapid deforestation

Table 2.2-- Tropical Deforestation: The Main Fronts

Area	Forest Remaining in 1991 (sq. km)	Deforestation in 1991 (sq. km and %)	
Southern Mexico	58 000	5 000	12.9
Central America	88 000	4 100	5.1
Colombian Chocó	50 000	1 500	3.0
Western Amazonia	260 000	5 600	3.0
Southern and Eastern Amazonia	812 000	10 000	1.8
Northern Bolivia	66 000	1 700	2.6
Eastern Nigeria and Southwestern Cameroon	54 000	2 800	5.3
Madagascar	20 000	2 000	10.0
Eastern Myanmar (Burma)	125 000	6 000	4.8
Northern and Northeastern Thailand	51 000	4 900	8.8
Vietnam	53 000	3 500	6.6
Eastern Malaysia	98 500	4,300	4.4
Sumatra and East / South Kalimantan in Indonesia	375 000	8 800	2.3
Philippines	45 000	3 000	6.7
Totals	1 876 500*	63 400**	3.4

*Or 25% of all tropical moist forests totaling 7.5 million sq. km
**Or 43% of all deforestation totaling 148 000 sq. km
Source: Myers (1993)

million square kilometers or 32% of the ecobiome totaling 7 5 million square kilometers (Myers 1993 p 11) Although these areas are 'good news' countries one should remember that the classification is a relative and not absolute concept. That is they are thus classified because they are not in the super-critical stages as are others However they too could be in danger if commercial logging becomes an essential economic and financial alternative (Colchester 1994 Horta, 1991 Jagan 1996) and unsustainable forest management practices become the norm rather than the exception

The Future

A casual glance of the data on forest cover loss suggests strong global patterns of deforestation since the mid-seventies If we accept the trend as reasonably reliable then the most salient questions facing the policy community must address the scale and scope of future deforestation, its location and the rate at which it progresses

To assess these concerns it is more appropriate to consider a regional prognosis Table 2 1 reveales that deforestation rates across Africa Latin America and Asia & Oceania differ and increased over the two periods Using similar evidence Myers (1995 1991) assesses the future of tropical forests across Asia Africa and Latin America assuming the present situation persists unvaried. Outside of central Kalimantan (Borneo) Irian Jaya in Indonesia and Papua New Guinea little forest will remain in Southeast Asia in another 20 years It is believed

that in West Africa little tropical moist forest will probably survive beyond the year 2000. The lone forest area predicted to survive the purge is the Zaire Basin in Cameroon whose tract is sizeable enough to persist for several more decades. The future of Latin America's forests is no different from the prospects of the two previous regions. With the exception of major forest tracts in western Brazilian Amazonia and one Guyanas hinterland it is difficult to foresee how much forest can last beyond another few decades.

In addition to the foregoing projections there are other developments which portend challenging times for efforts to decelerate rates of deforestation. Acid rain it is believed will further exacerbate the situation by potentially affecting as much as one million square kilometers of tropical forests. It is already manifest in the forests of southern China (Zhao & Sun 1986; Galloway et al., 1987) and is expected to appear shortly in other regions and countries already plagued with a deforestation crisis (Myers 1995). Acid rain is most likely to be manifest in Indonesia, Peninsular Malaysia, southern Thailand, southwestern India, West Africa, southeastern Brazil, northern Colombia, and northern Venezuela (Lacaux et al., 1987; Andreae et al., 1988; Rodhe & Herrera 1988; Helas et al., 1990). Although areas of Guyana and Cameroon are considered safe havens, Colchester (1994) and Horta (1991) have their reservations. They report that in light of Southeast Asia's weakening forest resource base the international logging industry is now actively exploring new forest resource sites. Due to tropical developing

nations need for foreign exchange (Jagan 1996) the possibility of liquidating Guyana s and Cameroon's primary forest resources is very real

Agents of Forest Cover Loss

Having defined the scales of land cover change it is helpful to mention the most frequently cited agents of land cover change It will become evident that while not all agents are direct causes of land cover change they are contributors As such each agent falls along the continuum of definition Amongst the most frequently cited contributors are the permanent agriculture, forestry and energy sectors and the shifting cultivator

Agriculture

Conversion of forests for permanent agriculture (which includes land for pastures permanent crops and arable land) falls to the far right of the continuum indicating total deforestation In the 1981-1990 period permanent agriculture s share in deforestation in all tropical countries was estimated to be approximately 45% (Amelung and Diehl 1992)

Forestry

Forestry's contribution to land cover change accounts for approximately 2% to 10% of deforestation across all tropical countries in the 1981-1990 period (Amelung and Diehl 1992) and falls within the degradation/depletion categories

along the continuum. Forestry activities include the timber trade, logging activities and other trade in forest products. Although forestry and logging activities account for a relatively low share of global deforestation it should be noted that the forestry sector and specifically commercial logging activities catalyze the process of land cover change and thus indirectly contribute to deforestation (Johnson and Cabarle 1993). The catalytic process operates by opening otherwise inaccessible primary forests for other uses by establishing infrastructure (i.e. roads) that can be used by others afterwards (Amelung and Diehl 1992). Other less capital intensive economic processes then follow which continue depleting the forest long after commercial loggers have exited.

Shifting Cultivators

Shifting cultivators account for 41% - 49% of deforestation between 1981 and 1990 in all major tropical countries. These actors fall within the interior of the continuum between degradation and depletion. The "shifting cultivator"[5] has been blamed for the majority of tropical deforestation (Myers 1993), however it has been argued that holding shifting cultivators responsible for tropical deforestation is

[5]Ohlson (1990) (cited in Dove 1993) makes a distinction between transitional or opportunistic shifting cultivators and bona fide or traditional shifting cultivators. The former are entrepreneurs who follow logging roads to exploit new opportunities to produce commodities for the market but have no true ties or dependence on the forest for day to day survival. Traditional cultivators current and future survival on the other hand is inextricably linked to the forest ecosystem. Therefore opportunistic shifting cultivators tend to be more destructive to the forest.

tantamount to blaming the victim because the real causes are likely to be poverty unequal land distribution and low agricultural productivity combined with rapid population growth (Mahar 1989 p 2-3) Additionally without a catalyst such as commercial logging activities many shifting cultivators would not have access to what had been primary forests Therefore all ascriptions of blame must be put in context

Energy

Energy and electrical power generating activities accounted for approximately 2% of tropical deforestation across all tropical countries in the 1961-90 period (Amelung and Diehl 1992) Although relatively small these sectoral activities have significant effects on secondary forests by leading to greater degradation of forest ecology and changing forest ecosystem functions On the continuum energy and electrical power generating activities fall within the interior end are manifest in the degradation/depletion categories

While it is feasible to identify and target for blame particular sectors or agents the land cover change issue in general and the deforestation dilemma in particular are outcomes of sundry private and government policy externalities These are manifest in decisions regarding economic policies and instruments and property rights allocations Policy decisions to promote specific economic activities (such as those defined above) in the sensitive forest ecosystem ultimately affect the existing land cover through the various stages listed on the continuum

Summary

Review of the spatial temporal and behavioral dimensions of land cover change leaves a lingering sense of uneasiness If es the data suggest, the depletive pressures on tropical forests have increased over lime el e nonlinear rate and show little sign of easing then current times are indeed times of urgency The current perspective views forests and forest ecosystems to be essential contributors to the fabric of human societ and economic welfare Therefore greater comprehension of the complex processes and factors germane to the deforestation process will assist in efforts to mitigate the problem

CHAPTER 3
THE ECONOMICS OF DEFORESTATION

This chapter has two objectives. The first is to review some models used to investigate the process of deforestation in tropical developing countries. The second is to put into context the global policy environment on mitigating deforestation.

Economic Modeling of Deforestation

The literature on the economics of deforestation reveals that deforestation is a multifaceted problem of human behavior. Human behavior as it relates to production, consumption, trade, international finance, demography, and fiscal policy permeates economic analysis of deforestation and shapes the policy environment. Although the following discussion will separate and analyze sundry aspects of human behavior that influence the deforestation process, it should be understood that it is the confluence of human behaviors which drives the deforestation process. No single factor can be blamed for the loss of forest cover and its associated services.

Government Policy

Economic behavior is often influenced by government policy and this is the case for tropical deforestation. Government policy conditions the opportunity set available to economic agents using forested area. Developing countries frequently have forestry policies such as direct subsidies and lenient forest concession terms that foster unsustainable[1] use of forest resources. These *policies* induce *external dis-economies* resulting from both governmental and private actions. These actions tie to commercial agriculture (Mahar 1989), shifting cultivation (Myers 1993), forestry (Amelung and Diehl 1992) and energy (Palo et al. 1991). Encroachment occurring in the forest environment is a direct result of the policy, regulatory and enforcement process all variables in the government management matrix. In a strong sense it can be argued that government *policy externalities* share partial responsibility for tropical deforestation.

Empirical studies illustrate the role of government policy in inducing external dis-economies in the forest sector. Utilizing a recursive system of two equations, Southgate, Sierra, and Brown (1991) explore the social forces driving tropical deforestation in the eastern region of Ecuador. Treating agricultural labor force and deforestation (measured as the extent of land clearing in a region) as endogenous variables and urban population, soils, roads, and relative tenure security as

[1] Unsustainable is used in the sense that consumption and production activities exceed the regenerative capacity of the forest ecosystem, preventing the resource from effectively maintaining itself.

exogenous variables. It is demonstrated that population pressure, capital investment (inferred), tenure insecurity, and the prospect of capturing agricultural rents all significantly contribute to the acceleration of deforestation in Ecuador's eastern region. Most importantly, the institutional environment confronting settlers encouraged land clearing by tying formal use rights to income (tenure security) and productive property (cleared land).

The oft cited study, Government Policies and Deforestation in Brazil's Amazon Region, Mahar (1989) is a testament to the role of government in shaping the human/ environment interaction. Incentive based programs such as road building projects, investment tax credit for projects located in Amazonia, government sponsored settlement schemes, and subsidized credit lines represent examples of government activities which condition people's opportunity set and encourage land use changes. Mahar notes that:

> Pushed by poverty and skewed land distributions in their regions of origin, the settlers have merely responded to incentives created by the government in the form of access roads, titles to public lands, various public services, and, in the case of the Transamazon scheme, subsistence allowances. (p. 46)

Many of the decisions impacting the Amazonian environment were made before enough was known about the region's ecological system and in many respects were following the development policies utilized in the United States.

The lessons of the Amazon have gone unheeded. Similar land use changes and resettlement schemes are evident in other South American countries (Bolivia and Ecuador), Southeast Asian countries (Malaysia and Indonesia), and West

African countries In these cases it is easy to blame poverty stricken migrant populations (Myers 1993) for the loss in forest cover However one must ask to what extent government policies influence demographic changes via sponsored incentives and weak domestic policy and enforcement mechanisms In most instances the weak policy and enforcement environment are induced by economic development needs

Other alleged sources of tropical deforestation are the granting of logging concessions tropical timber extraction the burdens of foreign debt, and demographic changes Although commercial agriculture is identified as a major source of tropical deforestation it is not explicitly considered in this analysis since it results from distinct government policy already discussed or a residual effect of industrial logging

Logging Concessions

The majority of tropical forests are government owned (FAO/UNEP 1981 Vincent, 1992) Therefore permission must be granted in the form of timber concessions to fell trees for wood production and the international trade in timber and other log derivative products A body of literature debates the role of logging concessions in directly or indirectly causing tropical deforestation(Walker 1993 Poore et al 1989 Barbier et al 1994) The literature's consensus is that the granting of logging concession rights and leasing agreements generally suffer from weak formulation management inefficiency and lack of enforcement

Ideally logging concessions should be granted based on the length of the time period required for one full rotation and should contain stipulations for sustainable forest management (Barbier et al 1994) As it is often the case in developing countries the gap between theory and practice is large Most logging concessions are granted for short time periods (for a duration less than the full rotation cycle) lack incentives for reforestation and are not enforced by domestic governments For example Poore et al (1989) suggest that concession duration is a major problem of Southeast Asian forest management and concession size duration and renewal are important problems in attaining sustainable forest management in Africa

Industrial Timber Production and the Trade in Timber Products

Probably the most cited cause of tropical deforestation is the trade in timber products However evidence demonstrates that the international trade in timber products is not directly responsible for the actual clearing of forest lands (Barbier et al 1995 Burgess 1993) While industrial logging modifies the forest environment, it does not lead to totally clear forest areas Other factors such as bad forest management practices the conversion of forest land for agricultural use and harvesting of trees for fuelwood are considered to be greater contributors to the process of tropical deforestation Where timber production is a factor in deforestation it may have more to do with the poor management and regulation of

the timber stand after timbering than with the quantity of logs extracted from the stand

Based on volume domestic consumption of timber products seems to be more closely linked to tropical deforestation then the international trade in timber products Only 17% of the total tropical timber production is used for industrial purposes and approximately 6% of total tropical roundwood production enters the international market (Burgess 1993) Burgess (1995) suggests it is likely that increasing domestic consumption of timber due to rising incomes and population is the major cause of tropical deforestation rather than the international trade in timber products

A cross-sectional study of 72 tropical countries by Palo et al (1987) supports the positions of Barbier et al The authors assessed factors (population density trade in timber products and agriculture and livestock production) commonly attributed to the cause of tropical deforestation They found no significant relationship between the timber trade and industrial roundwood production Rather, significant variables included the share of forest fallow livestock production index agricultural area coverage food production per capita and population density

While the trade in timber products is not a direct cause of tropical deforestation it acts as a triggering mechanism by opening up the forest to other uses [2] This trade triggers the deforestation process by modifying and depleting

[2]Access to the previously impenetrable forest is facilitated by extensive road building a necessary condition for timber extraction

virgin forest stocks and thus facilitate secondary land uses of the degraded forest stand. In so doing, it completes the forested-to-the-deforested continuum described in chapter 2. This is the argument forwarded by Capistrano (1990) and Capistrano and Kiker (1995) as they demonstrate the significance of the international trade in timber products in influencing tropical forest depletion in a cross sectional study of 45 tropical countries. During the 1976-1980 period the authors found that as the export value per unit of tropical wood declined, developing countries compensated by increasing the volume of wood harvested.

Kummer and Turner (1994) in their analysis of Southeast Asia found a recurrent pattern of large-scale logging for export followed by agricultural expansion. Logging as a catalyst for additional forest cover loss is further supported by Amelung and Diehl (1992). They suggest a process of deforestation whereby timber extraction is largely responsible for the opening of previously unexploited forest to other economic uses, and leading ultimately to deforestation. All three studies demonstrate that where industrial logging is an important source for export revenues it tends to initiate a process of forest cover loss leading to depleted forest areas and eventually to totally cleared forest area (deforestation).

In cases where timber production has demonstrated a distinct influence on deforestation, there has been caution in attributing sole responsibility to the timber industry. Employing a cross-sectional model of 53 tropical countries, Burgess (1992, 1993) analyzes the relationship between timber production and forest clearance over the 1980-1985 period. The findings of the model support the

hypothesis that the trade in forest products indexed as 1980 roundwood production per capita has a positive association with forest clearance over the study period. Other findings include a positive association of the dependent variable trade in forest products with population density and the dummy variable for Latin America and a negative association of real GNP per capita with the dependent variable. Because previous statistical analyses and the author's own work provide limited evidence on the linkages between tropical timber production trade and tropical deforestation Burgess is cautious in attributing responsibility to the trade in timber products as the sole cause of tropical deforestation.

Foreign Debt

One dimension of the deforestation issue is the role of macro-economic objectives in the decision to liquidate forest resources. Kahn and McDonald (1995) explored the relationship between third-world debt and tropical deforestation under the premise that debt is a source of deforestation pressure. Their theoretical model suggests that debt amassed to finance a country's current economic constraints may lead to myopic behavior as manifested in less than optimal deforestation rates in the long run. Empirically the authors demonstrate a correlative link between debt and deforestation over the 1981-1985 period and establish that debt is an important factor in tropical deforestation. They conclude that reductions in debt may reduce the pressure to deforest although the direct effect is small

Capistrano (1990) and Capistrano and Kiker (1995) consider the influence of macro-scale factors in driving tropical forest depletion. They found a negative relationship between the debt-service ratio and tropical forest depletion during the 1972-1975 period. This finding suggests that ready availability of foreign loans during the four year period may have eased financial pressure on tropical countries therefore curbing the tendency to liquidate forest stocks to meet macro-economic constraints. Considering the advent of the international debt crisis and the results of Kahn and McDonald and Capistrano and Kiker, it appears that tropical countries tend to liquidate relatively more forest resources in financially challenging times than in better times.

Foreign exchange shocks may also be significantly related to tropical forest depletion. Capistrano and Kiker characterized the influence of debt and currency devaluation on tropical forest depletion by noting that exchange rate adjustments, in most cases a precondition for continued access to foreign loans, may be a contributing factor to tropical forest depletion. This is manifest through increased competitiveness of forest product exports and increased opportunity cost of keeping land under forest cover when agricultural commodities are more competitive on the world market.

Kahn and McDonald's regressions with total external debt as an explanatory variable were not particularly convincing; however, regressions involving relative debt were informative. Combining these results with Capistrano and Kiker's significant results on exchange rates and arable land suggests that real exchange

rate devaluation caused tropical countries to compensate for lost foreign exchange earnings by increasing the volume of primary exports. Essential foreign currency is garnered to service outstanding debt and sustain import demand. The pressure to increase the volume of primary exports is manifest by greater reliance in tropical countries on forest clearing to financially benefit from the international timber trade or increased demand for arable land to increase agricultural exports. Therefore it is not debt per se that drives deforestation in the 1981-1985 sub-period but the need for foreign exchange resulting from weaker currencies to meet a cross section of requirements, namely debt servicing and import demand. Capistrano and Kiker (1995) summarize their finding by stating:

> Higher debt service did not necessarily translate into greater forest depletion, particularly when international credit was readily available. It was not debt per se, but rather currency devaluation that seem to have been more strongly linked to tropical forest depletion. This would seem to support the impression that structural adjustments, with their accompanying currency devaluations, have had real and adverse consequences for the world's tropical forests. (p. 27)

Demography

Ensconced in the economics of deforestation literature is the role of the impoverished, marginalized inhabitants of the rural area. Population pressures are emphasized as an underlying cause of several primary sources of deforestation. The increased harvesting of logs, gathering of fuelwood, and the desire to convert forest and woodland areas to pasture and cropland all result from increasing rural

populations. As population growth increases, the demand for arable land also increases. Therefore, there is pressure to convert forest land to agricultural land.

Allen and Barnes (1985) conducted a cross-national panel analysis of the most frequently cited causes of tropical deforestation across 39 countries in Africa, Latin America, and Asia spanning the 1968-1978 time period. Results indicate that population growth, agricultural expansion, and the past rate of wood production have significant effects on deforestation. Moreover, for the ten year period countries with high population growth rates, high aggregate wood production, and rapid agricultural expansion tend to have above average rates of deforestation. Considering the term structure of influences on deforestation, the models indicate that short-term effects result from rising population and rapid expansion of agriculture, and long-term effects come from wood harvesting for fuel and exports. This study links the deforestation process to domestic influences (land clearing for agricultural expansion, demand for fuel wood, and rising population), and international influences (wood based exports and rising fuel prices). Additionally, it indicates that aggressive pursuit of income growth via wood based exports contributes to the deforestation process over longer time periods via cumulative time effects.

Rudel (1989) conducts a cross-sectional analysis of 36 countries spanning Africa, Asia, and Latin America to identify global patterns in deforestation and elicit causes of tropical deforestation during the 1976-1980 time period. The results indicate that 1) whether population is measured as total population growth or rural

population growth it has a significant correlation with deforestation 2) in countries which have small rainforests growth in rural populations was correlated with deforestation and 3) in countries with large forests capital availability via large scale investments in frontier regions accelerates deforestation In 1) and 2) the effect of population on deforestation could be indirect increasing population implies need for increased foreign exchange earnings as well as increased per unit area of productivity In light of 3) it is wholly possible that government could have been facilitating commercial logging along with opening roads into new areas The poor inhabitants of the forest did not build the roads that allow agriculture to be viable Noteworthy from this analysis is the insignificance of wood and agricultural exports in causing deforestation over the specified period

Cropper and Griffiths (1994) and Rudel (1989) found population to be significant influences on deforestation in cross national studies The former study found a concave relationship between income and deforestation among African and Latin American countries In addition while rural population density was found to increase deforestation in Africa it was insignificant in Latin America and Asia Rudel conducted a pooled analysis and found that population growth contributes to deforestation directly (by increasing the population which clears land) and indirectly (by increasing the demand for wood products in a country) Whether population grows and open roads and the forest or whether new roads allow the population to grow in the area and lead to cleared land is not clear from both studies These issues are two different possible cause and effects that matter

In more localized investigations, Southgate et al (1991) studied the causes of deforestation in Eastern Ecuador's Amazonia Lowlands and Pfaff (1996) considered driving forces behind deforestation in Brazil's Amazon. Southgate et al established that settlement of forested hinterlands is driven by the prospect of collecting agricultural rents and that deforestation is a consequence of demographic pressure and land tenure insecurity. As the authors note, land tenure security is a problem in all countries with extensive tropical forests and a necessary condition for establishing property rights is land clearing.

Using a model of optimal land use, Pfaff (1996) found that the provision of infrastructure (road density, government development projects, and proximity to an economic center) and better soil quality leads to greater deforestation. Population density is significant in deforestation when it is a sole explanatory variable but loses its explanatory power when mixed with other variables. Interestingly, a quadratic population specification suggests the importance of the spatial distribution of population but its effect is small.

In summary, the broader "Malthusian" idea that population growth contributes to high rates of deforestation seems to be confirmed by studies at the regional and global levels, but shows mixed results at the country level. It accounts for the contributions of shifting cultivators to the deforestation process, so fervently articulated by Myers (1993). However, care must be taken in attributing the cause of deforestation solely to population growth. Population growth is a source of deforestation pressure, but analyzed independent of access into the forests,

poverty considerations and income distributions it may bias analysis and throw conclusions into doubt

Synthesis

Influences on tropical deforestation are summarized in table 3 1 The table separates significant and insignificant variables from past empirical studies to facilitate analysis Statistically tropical deforestation is most influenced by variables relating to varying definitions of population followed by variables relating to land (land cover change forested area land constraint) variables relating to national income (GNP GDP) and variables relating to food production and agricultural productivity Least used but statistically significant variables in the deforestation process include references to wood consumption investment in road construction land tenure security soil quality and the exchange rate (real or nominal) The table also indicates the frequency with which listed variables were used in empirical analyses and were found statistically insignificant. In this category variables relating to income (GNP GDP) the value of agricultural exports and the value of wood (broadly defined) exports were found to have no consistent statistical influence on tropical deforestation

If we partition the analytical variables into categories of country specific variables and international specific variables it is evident that the majority of statistical analyses focus on country specific variables such as land land cover change population, income labor force and productivity Less evident is the use

Table 3.1-- Significant Variables Across Empirical Tropical Deforestation Studies

Empirical Study	DFA/ TA	Pop	Inc	Wd Fdn	Land Cnv	Lab Frs	Gov Inv	Land Ten	Soil Qlty	Debt & DS	Ag E:V	Wd E:V	Feed Fdn	Ag Pdty	RXR	Gov Cred
Southgate et al 1991		x				x	x	x	x							
Rudel 1988	x	x	x													
Palo et al 1987	x	x	x		x								x	x		
Burgess 1993	x	x	x	x												
Allen & Barnes 1985	x	x			x							x				
Kahn & McDonald 1995	x					x				x						
Southgate 1991	x	x									x			x		
Capistrano & Kiker 1995	x	x	x							x	x	x	x		x	
Barbier et al 1995		x	x	x												
Pfaff 1996	x	x	x				x									x
Cropper & Griffiths 1994		x	x									x				
**Ratio	9:1	10:1	7:2	2:1	2:1	2:1	2:1				1	3:2	2:1	2:1		1

Table 3.1--continued

*Allen and Barnes ran two regressions

**ratio of significant empirical finding to insignificant empirical finding

DFA/TA	change in forest area over total forest area (variable representing change in land cover)
POP	population
Inc.	income (as measured by aggregate measures or micro measures)
Wd Pdn	wood production (roundwood logs)
Land Cnv	land conversion
Leb Frc	labor force
Gov Inv	government investment into structures (roads highways etc.)
Lend Ten	land tenure security
Soil Qlty	soil quality
Dabt & DS	debt and debt service
Ag E V	agricultural export value
Wd E V	wood export value
Food Pdn	food production
Ag Pd'ty	agricultural productivity
RXR	real exchange rate
Gov Cred	government credit issuances

of variables relating to the international environment such as the real exchange rate, debt service, and agricultural and wood export value in analyses of influences on tropical deforestation. Such a finding is consistent with the prevailing idea that tropical deforestation is a local/national problem and not a global/international manifestation (Barbier et al. 1994). That is, local decision making entities such as governments, rural populations, and urban populations are responsible for the reduction in forest cover. Government's influence is manifest through distortionary public policies which transmit inefficient economic signals to private actors. Rural influences are effected through high fertility rates, expanding population, and greater demand for fuel wood and farmland. The urban influence is effected through over-populated urban areas and the need for food to feed the food dependent urban sector.

Open economy influences are less apt to be targeted as a significant influence on tropical deforestation because of the belief that the timber trade acts as an indirect influence on the process. As such, works like Burgess (1993) and Barbier et al. (1995) eschew financial considerations in their analyses as root influences on tropical deforestation.

While the case for the irrelevance of the tropical timber trade in the process of deforestation can be made for any one country, it is difficult to adequately defend the irrelevance of the open international economy in influencing natural resource use in tropical developing countries. Consequently, although prevailing facts indicate that the timber trade cannot be the sole cause of tropical deforestation

non-incorporation of other trade variables such as the exchange rate foreign exchange availability import demand and log and log derivative product prices leads to gross under-assesements of the causes and influences of tropical forest depletion. It is the objective of the present investigation to pave a new path into the tropical deforestation inquiry

The Global Policy Environment and Mitigation of Deforestation. An Approach

Analytical Framework

A simple framework for describing the global policy environment on alleviating the problem of global deforestation compares the marginal private cost and marginal social cost of forest transformation The approach will describe components of both costs explicitly state society's preferred equilibrium and assesses means by which the policy process has attempted to curtail the forest dilemma and achieve a socially acceptable equilibrium A working definitions of private costs social costs, private goods and social goods are essential to the discussion

Private costs. The private costs associated with forest transformation include the accounting costs of logging (sunk costs i e concessions wage rate capital costs fuel equipment) and roadway construction These are tangible economic costs with fair market values in the open economy

Social costs. In addition to the private costs the intangible costs of forest services lost are taken into account These include the costs associated with lost biological diversity lost revenue from other consumptive uses (harvesting of non-timber forest products recreational uses) lost or damaged ecological functions (watershed protection carbon storage and micro climatic role) and lost option and existence values The essence of social costs is to recognize the value of the forest as an ecological system with benefits transcending pecuniary measures Treated as an integrated system the losses accompanying system degradation or total system loss are borne in society's information matrix such that socially efficient decisions on resource use can be made

Private goods A private good is one that is characterized by rivalry in consumption or production Specifically it is a good which is depleted as a result of one economic agent's use and cannot be available in whole for another economic agent's use Where there is rivalry in production and consumption there is room for the market system to operate efficiently The private goods nature of forest production is manifest through the domestic and international trade in timber products (roundwood sawnwood plywood fuelwood industrially processed wood products and derivatives of wood products) and non-timber forest products (nuts berries rattan resin palm oil etc) Note however that outside of the regulatory arena private production and consumption economic activities typically ignore social costs These behaviors therefore yield externalities that contribute to the process of deforestation

Public goods. A pure public good is one that is characterized by non-rivalry in consumption or production. Specifically it is a good which is not depleted as a result of one economic agent's use and is available in whole for another economic agent's use. Where there is non-rivalry in production and consumption there is difficulty for the market system to operate unfettered. The public goods nature of forests and forestry production is manifest at the local (national), regional and global scales. Open access to a resource creates situations in which the social costs of production and consumption go unaccounted in individual decision making and therefore create externalities that contribute to the process of deforestation.

When society through representation by government grants forest resource use rights it should be with social costs in mind. Ideally society hopes that marginal private costs are nested in marginal social costs such that externalities from forest utilization are zero. However that is rarely if ever the case. Instead we tend to see an intersection of marginal social costs and marginal private costs which defines the area of consensus between private owners of property rights and those that wish to change property rights under the guise of the "social good." Within this shaded region social costs are met to the extent that pre-negotiated contracts contain provisions for silvicultural practices that preserve the forest resource and the public good characteristics of extant forests.[3]

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[3]In cases where property rights are nonexistent but open access activities compromise the forest environment then the private costs of transforming the forest resource are attributed to local governments who are responsible for conditioning the economic environment.

The non-intersecting areas represent regions of difference and therefore opportunities for negotiation or change. Currently the global public good characteristics of forests are the center of attention because past forestry management practices failed to safeguard the potential loss of global biodiversity and the consequences of global climatic change. Consequently the global agenda is to reduce non-intersecting areas and widen intersecting areas via global forestry programs and agreements.

Deforestation as an External Economic Cost of Human Behavior

The deforestation issue is salient and has garnered increasing attention in academic and international arenas. Emanating from this concern is a litany of policy alternatives, evaluations, programs, and principles regarding the preservation and regeneration of tropical forests. In essence current attempts seek to actively account for the social costs of forest destruction. The main actors involved include academics, tropical country governments, developed country governments, and international programs and organizations such as: Tropical Forestry Action Programme (TFAP), the International Tropical Timber Organization (ITTO), the United Nations Conference on Environment and Development (UNCED), and the World Bank. The crucial question which confronts them is stated as follows: How does the global society reduce the external costs of forest resource use while meeting tropical country economic objectives?

Evidence sufficiently establishes that people s uses of forest resources creates external economic cost The policy environment shapes economic incentives and thus directly influences human behavior and indirectly influences forest land use changes The nature of the economic externality emanates from the two types of goods provided by the forest private goods and public goods Consequently the policy environment s an external influence on both the private and public good nature of the forest Furthermore the economic externality emanating from the public good nature of the forest must be recognized at the local (national) regional and global scales How forest resources are used or transformed determines the rate at which forest cover is lost and the magnitude of deforestation

At the local scale the public good nature of forests is manifest through the role of forests in providing watershed protection erosion control flood control aesthetic value for current and future generations protection against unknown diseases and wildlife protection

At the regional level forests serve as an agent against flood damage through watershed protection and erosion control and shield neighboring countries from the potential economic consequences of the potential climatic change induced by the greenhouse effect. Clearly one country's benefit from the services of standing forests does not detract from another country's consumption of those services

At the global level the public goods nature of forests is manifest in the forest's stock of global biodiversity and protection against the climate effects of climatic change especially for the developed countries north of the equator

Transition from Old Policy Options to New Policy Options

Discussion of deforestation is at the vanguard of international environmental discussions because of the global public good properties of tropical forests Renewed interest in forest system's role and indigenous people's role in the drug discovery process in addition to sufficient scientific evidence linking changing northern climatic conditions to forest stock depletion have influenced considerations of the total economic value and consequences of forest system loss Naturally analysis of different social processes aimed at arresting the problem are inevitable These social processes vary from the use of economic instruments to increased regulation and global cooperation

Alternative forestry policy options have been explored and analyzed as potential solutions These include debt for nature swaps (Kahn and McDonald 1995) cartelization (Rauscher 1990) and international transfer of funds (Rauscher 1990 and Barbier and Rauscher 1994) tog import restrictions and bans (Barbier 1993 Vincent 1992) and market structure and changing the terms of trade (Barbier and Rauscher 1994) These options have been found to be short term and at best second-best solutions to the deforestation dilemma Only in the case of international transfer of funds is there great promise in reducing the rate of

deforestation however transfers would only be effective if implemented in a proper manner The likelihood of such welfare payments to the developing world from the developed world is minimal

It is recognized that developed countries also contribute to deforestation in tropical countries through their rising consumption of tropical timber This essential and growing demand is seen as an avenue for curbing deforestation in the market by means of product quality and differentiation Product quality in this case is measured by the products relationship with the environment. Differentiated forest products are ecologically certified by a reputable agency and it is hoped will garner higher prices if consumers are willing to pay higher prices for environmentally friendly products The idea behind ecological certification is that the market can play a role in mitigating the environmental and social impacts of forestry if consumers are provided information on the products' history [4] The socially conscious consumer will refuse to purchase ecologically unsound wood products which in turn would regulate producer behavior It is still too early to assess the relative success of ecological certification

World collective action through global programs and agreements are seen as the most comprehensive and effective means of mitigating the dilemma [5] The Tropical Forest Action Programme has created a framework for bringing developed

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[4]For a discussion of ecological certification see Kiker and Putz (1997)

[5]For a solid overview of global forest programs and agreements see Lyke and Fletcher (1997)

and tropical developing countries together. Its major aim is to slow tropical deforestation by helping countries formulate blueprints for environmentally sustainable forest management at the national, regional and global levels. The International Tropical Timber Organization is a vehicle for conservation concerns which has established targets and standards for sustainable tropical timber management. Its primary mission is to strike a balance between the needs of conservation and development and to secure more sustainable use of tropical forests and their inherent resources. The means of achieving this mission are through promoting cooperation, coordinating statistical data, and supporting research and development on marketing, utilization, reforestation, and management of tropical forests. The United Nations Conference on Environment and Development (UNCED) or "The Earth Summit" in Brazil facilitated the signing of global treaties to control global warming and biodiversity loss, and non-binding agreements were reached on a statement of forest conservation principles, and an articulation of the concept of sustainable development specific to forestry.

The World Bank is the major international organization focused on funding economic development. It has in the past funded development projects in tropical developing countries that caused or facilitated extensive deforestation and other undesirable impacts on forest resources. In 1987 the Bank conducted an environmental review which resulted in the organization adopting a new forestry policy. It's new policy articulates that the Bank intends to promote the conservation of natural forests and the sustainable development of managed forestry resources.

Stated objectives include the Bank's support for international efforts and legal instruments to promote forest conservation, assistance to governments in policy reform and institutional strengthening, creation of additional forest resources, and support for initiatives that preserve forest areas. Noteworthy is that the new policy requires environmental assessments before new projects are initiated and prohibits the financing of commercial logging in virgin moist tropical forests under any circumstances.

Global agreements and programs are an important first step in arresting the deforestation dilemma. However, these strategies cannot succeed without the articulation and substitution of real alternative means of acquiring foreign assets for needy tropical developing economies. The important question arising from this analysis is how do we bridge the short-and long-term loss of e foreign exchange sources to tropical developing economies to ensure that macro-economic objectives are maintained. A related question concerns the asymmetry between OECD commitment to preserving tropical forest resources for the global public good characteristics and their commitment to financing the lost revenues to tropical economies agreeing to tighter regulations of their forest management practices. Sandler (1993) notes that

> the positive externalities conferred on developed countries in terms of gene pools and carbon storage should provide an impetus for these nations to assist in the preservation of tropical forests. This impetus can be strengthened greatly if developed countries recognize the tropical countries' property rights to genetic materials gathered from their forests by giving them a share in the earnings from medicinal and other discoveries. Without these property rights, tropical nations will be less concerned about the public

> goods that their biologically diverse forests provide to the developed world If properly motivated the governments in tropical countries will rethink misdirected policies such as subsidizing [inappropriate] activities (p 233)

The willingness of developed nations to share earnings from medicinal and other discoveries from the tropical forest with tropical countries was tested at the 1992 UNCED Earth Summit in Rio The United States refused to sign the biodiversity treaty which sought to protect the tropical nations property rights to genetic material gathered from their forests Such reluctance to cooperate and share in capital gains from drug discovery coupled with the push for smaller government sectors and shrinking aid disbursements portends challenging future times for forestry and deforestation As the world attempts to increase the sharing of social costs in the private and individual costs of forest production the world's forests are being depleted Sandler (1993) likened current deforestation trends and the mercurial and strategic policy process to Rubinstein's (1982) bargaining model in which two players negotiate over a shrinking cake He notes that "if the objective of the negotiations (i e the benefits derived from the forest) is shrinking in time then an early [*and effective*] agreement will yield a greater sum of payoffs to the participants than a later agreement" (p 232)

Summary

It is clear that deforestation is a multifaceted problem of human behavior and social organizations This chapter identified central economic forces which generate negative external economies affecting the tropical forest ecological system These

externalities jeopardize the local and global public good characteristics of extant forests. Actors identified as generating externalities are domestic consumers, developed country consumers, international timber firms, international development institutions, domestic governments and policy makers, and shifted cultivators. Activities creating externalities are identified as logging, commercial agriculture, forestry, shifting agriculture, energy generation, and domestic and international wood consumption.

Industrial logging is constantly targeted for debate in influences on deforestation. Where industrial logging and the trade in timber products is targeted as a primary driving force behind tropical deforestation, the evidence is inconclusive. The debate has two strands of thought.

Although all parties agree that logging and timber trade activities depletes the forest stand, there is disagreement on the nature of their contributions to tropical deforestation. One strand of thought argues that commercial logging's contribution to the deforestation process is indirect. Since opportunistic actors follow logging trails, these actors should be held accountable for the complete loss in forest cover or degraded forest stand. Such advocates tend to blame weak legal and enforcement institutions for failing to protect the forest resources. The second strand argues that commercial logging's contribution is direct by virtue of the logging operation's role in facilitating the access of other economic actors to impenetrable forests. Thus, logging acts as the principal and most important economic actor in initiating the deforestation process. These advocates blame

foreign debt burden increasing demand of developed country consumers and the vagaries of the international market for the need of a tropical country to liquidate forest resources Institutions are recognized as lacking in effectiveness however, their weakness is a result of financial constraints Consequently forests suffer due to the need to export timber for needed foreign exchange and the lack of resources to finance protection of the forest stand once compromised

Acknowledging the complexity of the problem the central role of logging activities the domestic policy environment and the need for protecting global biodiversity and slowing the greenhouse effect the current trend in mitigating global deforestation is to promote international programs treaties and agreements to promote sustainable forestry Whether the change in the policy environment will be effective is a function of how successful developed and developing countries are in forming strategic environmental alliances Such alliances should have potential for procuring alternate means of generating foreign currency while maintaining tropical countries domestic macro-economic objectives The social value of forests and forest ecological system depends crucially on the temporal and spatial dynamics of this change in policy

The next chapter explores conceptually the relationship between foreign asset availability foreign debt trade in forest products and their influence on the forest area industrially logged While allusions to their relationship can be extracted from the literature a formal investigation does not yet exist

CHAPTER 4
CONCEPTUAL MODEL

The previous two chapters defined the scale and scope of tropical deforestation and evaluated the literature on the economics of deforestation. The current chapter isolates one agent of deforestation, industrial logging, and conceptually models the relationship between foreign asset availability, forest products trade, stress from foreign debt, and the forest area industrially logged. The chapter is organized as follows. First, an overview is given, followed by model specification and results from the model. The chapter closes with a summary of important findings.

Overview

The model is developed to theoretically assess the influence of forest products trade, foreign asset availability, and stress from foreign debt on the forest area industrially logged. The analysis focuses on the relationship between the decision to produce timber or processed goods that are based on tree extraction from the tropical moist forest (TMF) and the availability of foreign assets. The working assumption of the model is that the decision to cut trees to produce timber and forest products catalyzes the deforestation process.

The basic structure of the model is similar to Reuscher (1990) and Barbier and Reuscher (1994). Reuscher specifies an optimal control model in which the country's objective is to maximize consumption subject to two constraints: a foreign asset constraint and a forest stock constraint. The forest stock at any time is represented by a forest regeneration function less the product of an exogenous deforestation parameter and the quantity of timber produced and exported. Barbier and Reuscher (1994) specify an optimal control model in which timber products can either be exported or consumed domestically; forest product export earnings are used to import domestic consumption goods from abroad; and the tropical forest has positive stock externalities. The country's objective is to maximize domestic forest products consumption, imported goods consumption, and the tropical forest stock subject to a trade balance constraint and a forest regeneration function constraint identical to Reuscher (1990).

The present model differs from past efforts in several respects. First, foreign debt is assumed to enter the objective function of the tropical forest economy. This inclusion recognizes the need for ready availability of foreign financial capital in the developing economy. Second, forest clearing is an implicit function of several variables rather than specified as the product of a rate of deforestation parameter and volume of logs removed from the tropical forest. This facilitates understanding by eliciting marginal effects on the forest area commercially cleared. Third, debt, financial distress, and domestic output are included as additional state variables. These facilitate the analysis of debt on the decision to clear forest areas. Fourth,

domestic credit creation is included as a control variable. This enables the analysis to elicit the effect of domestic money changes on the decision to clear forest areas. Finally, included is a constraint on one of the control variables: the aggregate volume of forest product removed. This is merely a recognition that the quantity of domestic wood removed cannot be less than the sum of wood traded or consumed domestically. The constraint yields the scarcity value of domestic forest products.

Like previous works, the present analysis does not model other production or trade sectors since such inclusions would complicate the analysis without yielding greater insights into the relationship between foreign reserve demand and tropical forest depletion. Therefore, the model explores the increment of gain to the economy from transforming the tropical moist forest while ignoring other incremental gains from other economic activities.

The Model

The analysis will employ the following notation: a derivative of a function is represented by a prime; a dot above a variable denotes its derivative with respect to time t; and a hat its growth rate. The following variables, parameters, and functions will be used:

$N(t)$	size of the tropical moist forest (TMF) in volume roundwood equivalent
P_x	export price index for aggregate forest products
P_{xi}	domestic price index for aggregate forest products

P_m	price index for aggregate imported goods
P_d	domestic price index
a_f	foreign assets from forest product exports
a_{nf}	foreign assets from other sector's exports
C(t)	domestic credit
K(t)	capital stock
L(t)	labor
D(t)	new foreign debt disbursement
FS(t)	financial distress
Y*	index for OECD income
$A(a_f, a_{nf}, z, t)$	foreign assets
z=z(M, Y, D, t)	other variables in z
$M(P_m, P_d, Y, t)$	aggregate import demand
$Y(K, L, A, C, t)$	total domestic output
$q_x(P_x, P_{fd}, Y^*, t)$	forest products export supply
$q_{dom}(P_x, P_{fd}, Y, t)$	forest products produced and consumed domestically
$Q(Y, q_x, t)$	volume of wood removed from TMF
i	interest rate on debt
Θ	rate of growth of financial distress
	($\Theta = d(\ln A) / d(\ln D)$, Θ is non-negative)
r	interest rate on acquired assets
β	rate of growth of domestic output

δ	social discount rate
p	marginal propensity to secure income through industrial logging of forest areas
α	annual allowable cut (AAC) [(volume/hectare)/t]
$g(N(t))$	regeneration function (volume/t)
	$(g(0) = 0 \;\; g(N^{max}) = 0 \;\; g''(N(t)) < 0$ and $N^{max} > 0)$
$H(Q\ p*Y\ M\ D\ t)$	forest area depleted in hectares
	$p = \Delta_0 + \Delta_1 FS$ where Δ_0 and Δ_1 are coefficients
	$(H(0) = 0 \;\; H(Q^{max}) = 0, \; H'(Q(t)) > 0 \;\; H''(Q(t)) < 0$ and $Q^{max} > 0)$[1]
$k(q_n(t))$	cost of forest products production
	$(k(0) = 0 \;\; k'(q_n(t)) > 0 \;\; k''(q_n(t)) > 0)$
$p(q_n(t))$	inverse demand function for forest products
	$(p'(q_n(t)) < 0)$
$R(q_n(t))$	profit function for forest products
	$(R(q_n(t)) = q_n(t)\, p(q_n(t)) - k(q_n(t)) \;\; R'(q_n(t)) > 0 \;\; R''(q_n(t)) < 0)$
$U(Q\text{-}q_n\ M\ N\ D\ t)$	welfare function $(U'(\,) > 0 \;\; U''(\,) < 0)$

Several comments are in order. First is the separation of capital into physical capital stock and financial capital stock in the domestic output function $Y(K\ L, A, C\ t)$. This distinction is important since it is assumed that monetary policy

[1]Note that $A(t)$ and $C(t)$ do not enter directly into the commercial forest clearing function $H(\,)$ but indirectly through aggregate import demand, national income and aggregate wood removal. It is hypothesized that the demand for foreign exchange by itself does not lead to forest clearing.

does affect output in developing countries[2] and sufficient access to and availability of foreign capital is an essential input into their growth and development process. Additionally, foreign capital is specified as a function of foreign exchange earnings from the forestry sector (a_f) and non-forestry sector (a_{nf}) and other determinants (z) of foreign capital availability in the current period. These other determinants include aggregate import demand, gross national income, new debt issuances, and the real interest rate.

Second, the volume of wood commercially removed from the tropical moist forest is assumed to be determined by national income and the level of forest products export demand. The domestic market is not stated as a determinant of commercial wood removal because it is assumed the potential to earn foreign reserves influence the government to issue logging concessions, and therefore underscore the importance of the forest product export market.

Third, it is assumed that the forest stock, N, and the level of foreign debt, D, yield positive external benefits as manifested in their inclusion as arguments in the utility function, $U(Q-q_{\infty}, M, N, D; t)$. Logging activity to produce timber is one of several activities which yield benefits to the economy. Other functions such as the forest's role in maintaining forest ecosystem functions, balance the hydrological cycle, control flooding and sedimentation, and produce non-timber products essential to local forest community economic survival are recognized in this modeling framework. It has never been stated that developing countries do not

[2]This is similar to Sinai and Stokes (1972) in the developed country context.

value their endowment of forest resources However it is recognized that these resources are liquidated as the best alternative to meeting domestic macroeconomic needs

Access to debt and maintaining creditworthiness are fundamental requirements for healthy business growth The objectives of countries are not different from private firms in the sense that capital is the fuel that stimulates growth As such foreign capital in the form of debt is welcomed by countries to finance economic growth However too large a debt can be deleterious As an input it indicates that an objective of the country is to facilitate access to foreign loans by maintaining creditworthiness

Finally financial distress is defined by Livingston (1993) as the condition in which a firm is in imminent danger of default due to its fixed charges (interest payments) exceeding its profits (earnings before interest and taxes) Recognizing that at the country level imminent financial distress will alert policy makers to make provisions for basic need we can define financial distress in this model's context as the state in which a country is in imminent danger of default due to its fixed charges (interest payments) exceeding its gross national (domestic) product less basic subsistence requirements

Livingston states that financial distress does not inevitably lead to default since there are several courses of actions prior to defaulting on interest payments These include the sale of assets for the acquisition of financial proceeds to pay

interest,[3] the acquisition of new monies either via new loans or renegotiation (or rescheduling) of the old loans [4] payment of interest with funds needed to replace depreciating equipment,[5] and solicitation of government (foreign) assistance which depends on the current political climate and economic importance of the firm (country)

In the case of a firm the cost of financial distress is lost sales (Livingston 1993) but for tropical countries which depend on primary forest resources for foreign financial capital the cost is the lost ecological base due to unsustainable forest production The economic consequences go beyond the pecuniary costs (such as lost revenue from the timber trade) and include non-pecuniary environmental costs such as increased flooding lost soil nutrients lost biological diversity and destruction of animal habitat to name a few

To reduce clutter the argument of time dependent variables will be omitted throughout the analysis

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[3]Note that the assets of a firm in financial distress typically have a low market price (Livingston) The equivalent in the tropical forest economy case is low market prices for forest products (timber and processed goods)

[4]Typically new loans are financed at a higher premium interest rate and highly restrictive protective covenants

[5]This can be viewed as good in the short term because financial obligations are met but harmful in the long term because the strategy destroys the nations physical capital base

The country is assumed to maximize the present value of future welfare,

$$\underset{Q \; q_x \; M \; C}{MAX} \int_0^{\infty} U\,(\,Q - q_x \quad M \quad N \quad D\,) \exp(-\delta t)\, dt \qquad (4.1)$$

subject to the constraint

$$\dot{N} = g(N) - \alpha\, H(Q \quad pY \quad M \quad D) \qquad (4.2)$$

$$N(0) = N_0 \text{ and } \lim_{t \to \infty} N(t) \geq 0 \qquad (4.3)$$

$$\dot{A} = R(q_x) \quad M + rA + (r - i)D \qquad (4.4)$$

$$A(0) = A_0 \text{ and } \lim_{t \to \infty} A(t) \geq A_{min} \qquad (4.5)$$

$$\dot{D} = (1 - r)D \qquad (4.6)$$

$$D(0) = D_0 \text{ and } \lim_{t \to \infty} D(t) \geq 0 \qquad (4\,7)$$

$$FS = OFS \qquad \text{where} \quad \Omega = \frac{d(\ln A)}{d(\ln D)} \qquad (4\,8)$$

$$FS(0) = FS_0 \text{ and } \lim_{t \to \infty} FS(t) \geq FS_{min} \qquad (4\,9)$$

$$Y = \beta * Y + M - q_x \qquad (4\,10)$$

$$Y(0) = Y_0 \text{ and } \lim_{t \to \infty} Y(t) \geq Y_{min} \qquad (4\,11)$$

$$Q \geq q_x + q_{dom} \qquad (4\,12)$$

with respect to the control variables Q, q_x, M, C and Lagrange multiplier ξ. The standard specification of a renewable resources allocation problem is represented by equations (4.2) and (4.3), the natural resources constraints (see Clark (1976)

and Plourde (1970)). The inter-temporal budget constraints are given by (4.4) and (4.5). Equation (4.4) represents the balance of payments. According to (4.5) foreign borrowing is constrained in the long run such that the budget constraint binds. Debt's characteristic is given by equations (4.6) and (4.7). Equation (4.7) states that there is a lower limit to the amount of debt that the international community is willing to loan. The burden of debt is manifest in equations (4.8) and (4.9). The equations state that change in the debt burden is an exponential function of the performance of loaned monies over time. Equation (4.10) shows that national consumption changes according to increased gross national income (GNI) and increased aggregate imports and falls through aggregate forest product exports. Consumption in the domestic economy is non-negative and must meet a minimum requirement as demonstrated by equation (4.11). The constraint on forest commodity production is given by (4.12). Equation (4.12) states that the total volume of wood removed from the TMF is at most the aggregation of volume of forest products demanded at home and abroad.

Results

Optimality Conditions

The Lagrange function of this problem is composed of the current value Hamiltonian augmented by a constraint on one of the control variables, Q. It is specified as

$$
\begin{aligned}
B &= U(Q - q_x \quad M \quad N \quad D) \\
&+ \lambda[g(N) - \alpha H(Q \quad pY \quad M \quad D)] \\
&+ \mu[R(q_x) - M + rA + (r - i)D] \\
&+ \psi[(r - i)D] + \gamma[\Theta FS] \\
&+ \phi[\beta + Y + M - q_x] + \xi[Q - q_z - q_{emm}]
\end{aligned} \tag{4 13}
$$

where λ μ ψ γ and ϕ are the co-state variables or the shadow prices of the tropical moist forest foreign assets new foreign debt disbursements financial distress and consumption respectively and ξ is the Lagrange multiplier or shadow price for volume of wood removed from the TMF

Differentiation of B with respect to the control variables Q q_x M and C and Lagrange multiplier ξ gives the necessary optimality conditions

$$\alpha \lambda H_Q - U_Q \quad q_x + \xi \tag{4 14}$$

$$\mu R'(q_x) - U_Q \quad q + \phi + \xi \tag{4 15}$$

$$\alpha \lambda H_M = U_M - \mu + \phi \tag{4 16}$$

$$\alpha \rho \lambda H_Y - \phi \beta \tag{4 17}$$

$$Q = q_x + q_{dam} \tag{4.18}$$

Changes in co-state variables are represented by

$$\dot{\lambda} = (\delta - g'(N))\lambda - U_N \tag{4.19}$$

$$\dot{\mu} = (\delta - r)\mu - \gamma\Theta_A FS \tag{4.20}$$

$$\dot{\Psi} = (\delta - (r - r))\Psi - \mu(r - i) + \alpha\lambda H_{\Theta} - (U_D + \gamma\Theta_D FS) \tag{4.21}$$

$$\dot{\gamma} = (\delta - \phi)\gamma + \alpha\lambda H_{FS} \tag{4.22}$$

$$\dot{\phi} = \delta\phi \tag{4.23}$$

Finally differentiation of B with respect to the co-state variables yields the respective equations of motion

$$\dot{N} = g(N) - \alpha H(Q - \rho Y - M - D) \tag{4.24}$$

$$\dot{A} = R(q_x) - M + rA + (r - i)D \tag{4.25}$$

$$\dot{D} = (i - r)D \tag{4.26}$$

$$\dot{FS} = \Theta FS \tag{4.27}$$

$$\dot{Y} = \beta Y + M \quad q_y \tag{4.28}$$

Since the Hamiltonian is concave in (Q q_x M, C N, A, D FS Y) these conditions are also sufficient for an optimum.

Economic Interpretation of Optimality Conditions

Equation (4.14) indicates that along the optimal trajectory the weighted total benefit $(U_c + E)/\alpha$ derived from the area commercially logged via consumption of one unit of forest product, must equal the marginal cost (λH_D) of land clearing due to the extraction of one unit of forest product today. Note that total benefits include the shadow value of the volume of wood removed from the tropical moist forest, ξ and is weighted by the productivity of the TMF. Also since extraction costs are

zero in this model the implied costs are user costs representing the future stream of forest products income foregone from commercial logging today

Equation (4 17) demonstrates that the alternative wealth benefits accruing from the area commercially logged $\phi\beta$ must equal the opportunity cost of generating income via commercial logging $\alpha\lambda\rho H_Y$

Equation (4 16) shows that along the optimal trajectory the weighted net benefits derived from imported products $(U_M + \phi - \mu)/\alpha$ must equal the marginal cost of forest depletion, λH_M due to national aggregate import demand needs

Equation (4 15) reveals that marginal profits from the export of forest products equals the weighted sum of costs associated with the export of forest products. These costs all weighted by μ the shadow price of foreign assets are comprised of the marginal utility of domestic forest products consumption the shadow value of an extra unit of forest product export, and the shadow value of an extra unit of log removed from the forest to satisfy domestic or export maket preferences

Assuming a binding aggregate forest products constraint equation (4 18) stipulates that the sum of national forest products consumed at home and abroad cannot exceed the quantity produced domestically

Combining equations (4 14) and (4 15) differentiating and substituting equations (4 19) (4 20) and (4.23) yields

$$R'(q_n) - r + \frac{g}{R}\frac{\phi}{\mu} + \frac{U_Q}{R}\frac{e_1 + \xi}{\mu} H_Q \quad (g + \frac{\alpha U_N H_Q}{R'\mu} - \frac{\gamma \Theta_A FS}{\mu}) \quad (4.29)$$

This result is the condition for the optimum rate of forest products production. The rate depends on the interest rate, the regeneration rate, various shadow values[6], the level of financial distress, the area commercially logged, the harvest parameter, α, national preferences for standing forest stock, marginal profits, and the change in the elasticity of debt due to changes in foreign assets. Assuming the growth rate of forest clearing is positive, the condition indicates that the rate of profit growth from the trade in forest products is increased by higher interest rates on holding alternative forms of wealth, increasing cleared forest areas, and greater domestic preference for wood extraction. Alternatively, profits and forest product exports are reduced by the marginal cost of liquidating the in situ forest stock. This latter term, which accounts for the inter-temporal user costs of the tropical forest, depends on several terms: the regeneration rate, $g'(N)$, the marginal social value for a unit of forest stock, U_N, the area commercially logged due to log extraction, H_α, financial distress, and the elasticity of assets with respect to foreign debt.

The time paths of the various co-state variables yields interesting insights. The model stipulates that the national forest stock has direct social value. Therefore equation (4.19) reveals that the rate of change in the shadow price of the tropical forest equals the difference between the opportunity cost of leaving a unit of the forest stock in situ, $(\delta - g(N))\lambda$, and the marginal social value of that unit, U_N.

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[6]These include shadow values for the forest stock, foreign assets, consumption and financial distress.

This result is identical to that obtained by Barbier and Rauscher (1994) and similar to Rauscher (1990).

An economy characterized by extreme financial distress has a high marginal value for foreign assets. This result is demonstrated by equation (4.20) which is a representation of the time path of the shadow price of foreign assets. The path is comprised of the sum of the opportunity cost of liquidating the forest stock to hold alternative forms of wealth, $(\delta - r)\mu$, and the marginal benefit of increasing foreign assets, $\gamma\theta_A FS$.[7] This condition implies that each developing country has a choice along its optimal trajectory: liquidate forest resources and invest acquired foreign assets to get a return reflecting the difference between the social discount rate and the market rate of interest, or utilize acquired assets to reduce financial constraints. If the latter action is proposed then current and future consumption, production, environmental options, and trading options will be less restricted. Clearly both have implications for the nature of the development path chosen by a specific country.

Equation (4.21) describes the time path of the shadow value of foreign debt. The condition indicates that the time path of foreign debt's shadow value is governed by the difference between the total opportunity cost of accruing foreign debt, $(\delta - (r - r))\psi + \lambda\alpha H_B - \gamma\theta_B FS$, and the total benefits of accumulating foreign debt, $\mu(r - i) + U_B$. The time path of the total opportunity cost of foreign debt consists of two terms which increase the shadow cost of debt: the net social rate of return of foreign debt, $\psi(\delta - (r - r))$, and the marginal cost of land clearing due to

[7]Note that $\Theta_A = -\Theta\, d(\ln A)$

foreign debt, $\alpha\lambda H_D$, and one term which decreases the social value of foreign debt debt's tendency to increase the magnitude of financial distress within the national economy $\theta_{SY}FS$.[8] Similarly the total benefits derived from accumulating foreign debt is composed of two items the societal benefit from having access to foreign debt U_D and the net return or profitability of foreign debt, $\mu(r - i)$. Whereas foreign debt tends to be costly in terms of increasing a country's vulnerability to financial distress and environmental stress this vulnerability can be reduced or offset by supra-normal returns on debt (i.e. the return associated with the investment of debt is greater than the cost of debt).

Equation (4.22) characterizes the time path of the shadow price of financial distress. This path is defined by the sum of the opportunity cost of an extra unit of financial distress from foreign debt $(\delta - \theta)\gamma$ and the marginal cost of forest clearing resulting from financial distress $\alpha\lambda H_{FS}$.[9] This condition is interesting because it has two interpretations each depending on the income level of the economy in question. If we accept the assumption that the demand for environmental quality is income elastic then we should expect that relatively more developed economies should have more institutional actors working to preserve extant forests. Therefore

[8] Note that $\Theta_D = \partial(\ln A)$

[9] In the current model $H_{FS} = \alpha Y\, \rho_{FS}$, where the expected sign of ρ_{FS} is positive. That is, as financial distress from foreign debt increases, the marginal propensity to secure income through industrially logged forest areas (ρ) is expected to rise. Making an extension to the area commercially cleared, it is expected that financial distress has a positive indirect influence on the forest area commercially cleared.

the stage of development, as measured by GNP could potentially indicate the incidence and duration of environmental degradation

In the context of the present work the second interpretation suggests that an economy below a critical level of income $Y = K^{c}$ will exhibit a marginal propensity to secure income through industrial cleared forest areas ρ which is positive The time path is then interpreted as changing according to the sum of the opportunity cost of an extra unit of financial distress from foreign debt $(\delta - \theta)\gamma$ and the weighted marginal income benefits from foreign loans $\alpha\lambda H_{FS} = \lambda Y \rho_{FS}$ Conversely an economy above a critical level of income $Y = K^{c}$ will exhibit a marginal propensity to secure income through industrially cleared forest areas which is negative This indicates that the time path changes according to the difference between the opportunity cost of an extra unit of financial distress from foreign debt $(\delta - \theta)\gamma$ and the weighted marginal income benefits from foreign financial loans $\alpha\lambda H_{FS} = -\lambda Y \rho_{FS}$ It is clear that the rate of change of the shadow price of financial distress is higher for a relatively poorer economy than it is for an economy that is not financially strapped The consequence of poverty in this case is a proclivity for the impoverished economy to compromise its environment and natural resource base to meet macroeconomic requirements

Equation (4 23) is the time path of the shadow price of consumption In this model the time path of consumption s shadow price is exponential and grows at a rate δ Along the optimal trajectory the cost and benefits of consumption are equal to the social discount rate

Partial Derivatives of Interest

The commercial forest clearing function is specified as a function of the volume of wood removed from the tropical forest, Q domestic output Y aggregate import demand M and debt D More formally the commercial forest clearing function is specified as

$$H = H(Q \quad \rho Y \quad M \quad D \quad t) \tag{4.30}$$

where the variables are as defined previously The effect of aggregate wood removal on the area commercially logged can be derived from necessary conditions (4.14) and (4.15) The effect is shown to be

$$H_Q = \frac{(\mu R \quad \Phi)}{\alpha \lambda}$$

$$or \tag{4.31}$$

$$H_Q = \frac{(U_{Q\,\Phi_Q} + \xi)}{\alpha \lambda}$$

which is nonnegative This conclusion is justified because marginal utility and the wood recovery parameter are always positive the shadow price of the tropical forest λ, is positive since an increase in the resource endowment yields an increase in exports and therefore an increase in consumption which is welfare improving and the multiplier on volume of wood removed from the tropical forest

is positive too since it represents e scarcity rent similar to the shadow price of the tropical forest By this reasoning it is reasonable to conclude that $\mu R \geq \phi$

Nationel income s effect on the area commercially logged is reasoned to have an embiguous effect The derivative calculated from necessary condition (4 17) is characterized as

$$H_Y = \frac{\beta\phi}{\alpha\rho\lambda} \qquad (4\ 32)$$

The s gn of ϕ is positive since output is produced from competing means λ end α is justified as before and the growth rate of income β is assumed positive The sign on ρ cannot be determ ned apriori Assuming that the demand for environmental quality is income elastic it is postulated that below a critical level of income $Y = K^{1}$ the area commercially logged will nse for e given increase n income end above this critical level of income the area commercially logged will fall for e given increase in income Stated alternatively the stage of development of the particular developing country will determine environmental response to e nse in income Relatively developed economies will exhibit negative marginal propensities to secure income via commercial logging while relatively less developed economies will exhibit positive marginal propensities to secure income vie commercial logging Whether H_Y is positive negative or zero is an empirical question depending crucially on the sign of the marginal propensity to secure income via commercial logging ρ

The income perspective and environmental perspective of many developing nations are typically at odds These countries often adopt the position that the United States and other developed countries utilized (i a compromised) the integrity of the environments and natural resources as a means to promote economic growth and economic development. Thus precedence exists for environmental and natural resource degradation

The effect of aggregate import demand on the area commercially logged is derived from necessary condition (4 16) and is characterized as

$$H_M = \frac{(U_M - \mu + \phi)}{\alpha\lambda} \qquad (4\ 33)$$

where ϕ μ α and λ are all positive according to previous reasoning and U_M is positive because the utility function is a monotonically increasing function of its arguments The sign of the effect aggregate import demand has on the area commercially logged depends on whether the total benefits of imported goods consumption financed by commercial logging, $(U_M + \phi)/\lambda$, exceeds the cost of financing imported goods consumption μ/λ Therefore H_M can be positive or zero depending on the relationship between costs and benefits of financing imported goods The possibility of H_M being negative is ignored since such a sign does not make practical sense [18]

[18] A negative sign can be obtained solely through the case of continuous and substantial international grants The possibility of a global welfare state is unlikely given the discussions in chapter 3

Commercial Logging, Forest Stock, and Equilibrium

The relationship between the rate of change of log extraction and the forest stock is of general interest. By combining equations (4.14) and (4.19) one obtains

$$\frac{\dot{Q} - q_x}{Q - q_x} = \frac{U_Q \quad q_x + \xi}{\eta \; U_D \quad q_x} \; [\,(\delta \quad g^{\prime}) + H_Q \quad (\frac{U_N}{\lambda} + \frac{\xi}{U_D \quad q_x + \xi})\,] \qquad (4.34)$$

where η is the elasticity of marginal utility and the other variables are as previously defined. Utilizing (4.34) and conditions (4.2) (4.3) (4.16) (4.17) (4.18) (4.21) (4.22) (4.25) (4.26) (4.27) and (4.28) one can solve for an optimal saddle path and the long run equilibrium. As the system is in equilibrium when the user costs the logging rate, domestic and imported consumption, financial distress, domestic credit creation, and the forest stock are constant, the equilibrium can be characterized by the following system of equations

$$\begin{aligned}
H_M &= \frac{H_Y \, p}{\beta} \, [\, 1 + \frac{U_M - \mu}{\Phi} \,] \\
\dot{\psi} &= (\delta - (\nu \quad i))\psi \quad \mu(r \quad i) + \alpha\lambda H_D - (U_D + \gamma O_D \, FS) \\
\dot{\gamma} &= (\delta - \Theta)\gamma + \alpha\lambda H_{FS} \\
\dot{A} &= R(q_M) - M + rA - (r - i)D \\
\dot{D} &= (\nu \quad i)D \qquad (4.35) \\
\dot{FS} &= \Theta FS \\
Y &= \beta Y + M + q_{stock} - Q \\
N &= g(N) - \alpha \, H(Q \quad pY \quad M \quad D) \\
\frac{\dot{Q} - q_x}{Q - q_x} &= \frac{U_Q \quad q_x}{\eta \; U_Q \quad q_x} \; [\,(\,\delta - g^{\prime}\,) + H_Q \quad (\frac{U_N}{\lambda} + \frac{\xi}{U_Q \quad q_x + \xi})\,]
\end{aligned}$$

where equilibrium values of N and Q are assumed and where explicitly specified will be denoted by asterisks Total differentiation of the system of equations (4 35) with respect to N Q Y M D FS A C and q_x can lead to a characterization of the equilibrium state and trajectories leading to that state In order for this system to guarantee that the curve $\dot{Q} = 0$ is positively sloped and cuts the curve $\dot{N} = 0$ from below therefore yielding a unique equilibrium the determinant BS of the Hessian matrix of the system of equations (4 35) must be negative (i e BS < 0) The condition implies that the equilibrium is a saddle point, and that the saddle path is positively sloped. Using these results the optimal solution is represented graphically in Figure 4 1

As in Barbier and Rauscher (1994) the solution suggests an equilibrium forest stock $\bar{N}$ determined by equating the social discount rate and the rate of return from holding on to the forest stock This result is characterized as

$$\delta = g'(\bar{N}) + \frac{U_N H_Q}{U_{\bar{B}} q_x + \xi} + \frac{\xi}{U_{\bar{B}} q_x - \xi} \dot{H}_Q \qquad (4\ 36)$$

Defining the maximum sustainable yield (MSY) as the crest of the $\dot{N}$ curve Figure 4 1 indicate that equilibrium will occur to the left of the MSY at (A) and (B) in the figure are $g(N) > 0$ and to the right of the MSY if (C) is $g(N) < 0$ Moreover it is evident that given a high initial level of forest stock (i e $N_0 > \bar{N}$) the economy will commercially clear a portion of its forest area

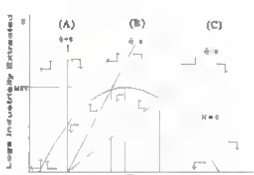

Figure 4.1--The Long Run equilibrium of the tropical Forest Economy

If the nation has zero preference for standing forests (i.e. $U_N = 0$) then the equilibrium forest stock, N^{**} would occur at

$$\delta - g'(N^{**}) + \frac{\xi}{U_Q \quad q_x + \xi} - \bar{H}_Q \qquad (4.37)$$

thus yielding upward sloping curves everywhere to the left of the equilibrium points occuring under the condition of positive forest stock externalities. Additionally this result demonstrates that $N^{**} < N^{*}$, indicating that an economy valuing only transformed forest stocks will tolerate lower levels of tropical forest in the long run than will an economy which considers non-economic forest functions as well as economic functions.

Additional Partial Derivatives

To evaluate the effect of profits foreign assets foreign debt financial distress domestic credit, and forest product exports on the area industrially cleared an expression relating the area industrially cleared to the model s variables is derived Manipulating equations (4 17) (4 19) (4 23) (4 24) and (4 27) The resulting equation is

$$H = \frac{g(N)}{\alpha} \quad \frac{(\delta - g')\lambda}{\alpha(\lambda g'' + U_{NN})} + \frac{\left[\frac{\bar{\lambda}^2}{\lambda} + \left(\beta^2 - \frac{\bar{\beta}}{\rho}\right)\left(1 - \frac{1}{H_Y}\right)\lambda - \frac{\lambda}{H_Y}\right]}{\alpha(\lambda g'' + U_{NN})\left(1 \quad \frac{1}{H_Y}\right)} \qquad (4\ 38)$$

Using (4 38) the effect of forest product export profits on the area industrially logged is

$$H_{R(q_4)} = - \frac{\lambda \Delta_1 \theta_A FS}{\rho \alpha (\lambda g'' + U_{NN})} \qquad (4\ 39)$$

Therefore foreign reserve demand met through forest product exports increases the forest area industrially cleared if the the marginal propensity to obtain income via industrial logging ρ is less than zero [1]

[1] The sign follows since $(\lambda g'' + U_{NN}) \leq 0$ and $\Delta_1 \geq 0$

Foreign assets from forestry activities affect the area commercially cleared via

$$H_A = - \frac{\lambda \Delta_1 FS Y_A (A_Y + A_M M_Y)}{\rho \alpha (\lambda g'' + U_{NN})} [(\frac{2 \Delta_0 \Theta + r\rho}{\rho}) \Theta_A + A \Theta_{AA} + D \Theta_{DA}] + \frac{\lambda \Delta_1 FS Y_A}{\rho \alpha (\lambda g'' + U_{NN})} \Theta_A M_Y \quad (4.40)$$

This expression is difficult to sign The effect of foreign asset depends on the sign of ρ and the time paths of total foreign assets and debt.[12]

The effect of foreign debt on the area commercially logged is

$$H_D = \frac{\lambda \Delta_1 FS}{\rho\alpha(\lambda g'' + U_{NN})} [(O_D - \Theta_A) (r - i) - \frac{2 \Theta \Delta_0 (\Theta_D + \Theta_A A_B)}{\rho} - (A + D A_D) \Theta_{AD} - (A \Theta_{AA} + \Theta_A r) A_D] \quad (4.41)$$

whose sign also depends on ρ and the time paths of total foreign assets and newly acquired foreign debt [13]

The affect of financial distress on the area commercially logged is

$$H_{FS} = \frac{\lambda \Delta_1 \Delta_0}{\rho^2 \alpha (\lambda g'' + U_{NN})} (2 \rho \Theta \quad O_A \dot{A} \quad O_D D - \Theta^2) - \frac{\lambda \Phi \beta \Delta_1 (1 - \lambda)}{\lambda (H_Y - 1)^2 \rho^2 \alpha^2 (\lambda g' + U_{NN})} \quad (4.42)$$

---

[12] Note that $\Theta_{AA} = 2 \Theta [d (\ln A)]^2$ and $\Theta_{AB} = [d(\ln A)]^2$ and the partial derivatives Y_A, A_Y A_M and M_Y are ≥ 0

[13] Note that the partial derivative $A_{BD} > 0$

whose sign depends on p β and the time paths of total foreign assets and newly acquired foreign debt.

The effect of domestic credit works out to be

$$H_C \quad \frac{\lambda \Delta_1 FS \, Y_C}{p \alpha (\lambda g' + U_{NN})} \left[\frac{2 \Delta_1 FS \, \Theta \, \Theta_A \, (A_Y + A_M M_Y)}{p} \right. \\ \left. + M_Y \Theta_A - (\Theta_{AA} + r \Theta_A) (A_Y + A_M M_Y) \right] \qquad (4.43)$$

whose sign depends on p since $Y_C \geq 0$

The influence of forest product exports on the area commercially cleared is expressed as

$$H_{q_x} - \quad \frac{R' (q_x) \lambda \Delta_1 \Theta_A FS}{p \alpha (\lambda g' + U_{NN})} \qquad (4.44)$$

whose sign depends on p

The final result characterizes the influence of the growth rate of national income on the forest area industrially logged It is defined as

$$H_\beta = \frac{\lambda \Phi (1 - \hat{\lambda})}{p (H_Y - 1)^2 \alpha^2 (\lambda g'' + U_{NN})} \qquad (4.45)$$

clearly determined by the sign of p and the growth rate of the shadow value of the forest stock $\hat{\lambda}$

Summary of Results

Conceptual results for exogenous influences on the forest area industrially logged are summarized in Table 4.1. Unconditional negative influences were derived for the aggregate volume of wood removed from the tropical moist forest Q_t and aggregate import demand M. Conditions for directional influences of gross national income Y, the growth rate of gross national income β, forestry profits $R(q_t)$ and forest product export supply q_t are also derived. The influences depend on the behavior of the marginal propensity to obtain income via industrially cleared land, ρ. In the case of revenues and exports, if this value is positive, forest stock is conserved and if this value is negative forest stock is depleted. However for income, forest stock is conserved if ρ is negative and depleted if ρ is positive.

The effect of the growth rate of income on industrially cleared land is not evident; however, it's sign is a determined by the signs of ρ and the growth rate of the shadow value of forest stock, $\hat{\lambda}$. If forest stock is disappearing then the growth rate of the shadow value of forest stock is strictly positive, therefore the effect of the growth rate of income on industrially cleared land depends on the sign of ρ. If ρ is positive then the growth rate of income conserves forest stock, and a negative ρ implies that the growth rate of income depletes forest stock.

Like previous works this conceptual framework could not state conclusively that the demand for forest products in the international market has direct influence on the forest area commercially cleared. The table shows that the influence of

forest product exports depends on the sign of ρ. Crucial to answering this question in the present modeling framework is the sign of ρ and the significance of forest product export demand on affecting the decision to give concessions to log tropical moist forests. These issues will not be discussed here; rather, empirical issues will be addressed in Chapter 8.

Casual observation of deforestation data suggest that the marginal utility of forests in the tropics is low and close to zero. This is manifest via increasing rates of forest clearing in the tropics over the last two decades. The current model demonstrates that the time path of the shadow value of foreign assets is not only positively governed by the opportunity cost of holding alternative forms of wealth but also by the need to acquire foreign assets to reduce the burdens of debt which lead to financial distress. To reinforce the importance of foreign capital to tropical developing countries, evidence suggest that they continue to seek access to foreign loans despite their precarious financial positions. The confluence of low marginal value for extant forests, an unambiguously upward positive time value of foreign assets, and continued pursuit of foreign loans leads to "mined" forest resources.

The model shows that if the need for foreign capital is overwhelming, national income (output) objectives in the short-run and the long-run, and aggregate import demand influence the total volume of wood removed from the tropical moist forest. These variables have conditional and unconditional, and direct effects on the forest area industrially logged in tropical developing countries. However, variables which can be classified as capital (total foreign assets, new foreign debt issuances,

Table 4.1– Exogenous Influences on Tropical Forest Area Industrially Logged

Exogenous Variable	Influence on FAIL	
	Positive[a]	Negative[b]
Q	never	always
Y	$\rho < 0$	$\rho > 0$
M	never	$(U_M+\phi)/\lambda > \mu/\lambda$
$R(q_e)$	$\rho > 0$	$\rho < 0$
A	indeterminate	indeterminate
D	indeterminate	indeterminate
FS	indeterminate	indeterminate
C	indeterminate	indeterminate
q_e	$\rho > 0$	$\rho < 0$
β	$\rho > 0$	$\rho < 0$

[a]Positive indicates that the influence maintains or increases total forest area
[b]Negative indicates that the influence decreases total forest area

FAIL forest area industrially logged
Q volume of wood removed from the tropical moist forest
q_e volume of forest product exported
$R(q_e)$ profit from forest product exports
Y total domestic output
M aggregate domestic import demand
D New foreign debt disbursements
FS financial distress (index)
C quantity of newly issued domestic credit
U_M marginal utility of aggregate domestic import demand
ρ domestic marginal propensity to deforest
μ shadow value of foreign assets
ϕ shadow value of domestic consumption
λ shadow value of the tropical moist forest
β growth rate of gross national income

newly issued domestic credit and an index of financial distress exert influences on industrial forest stock that are not easily determined However complex these influences the conceptual framework suggests that foreign asset availability could potentially have an influence on the decision to clear industrial forest areas in tropical nations

For the majority of derivatives it is clearly an empirical issue to effectively state the direction of influences on the forest area industrially logged Nonetheless, it is evident that the marginal propensity to obtain income via industrial logging has a very strong influence on most derived results

Conclusion

This chapter analyzes the roles of the forest product trade and economic influences in determining the forest area industrially logged This focus is motivated by the assumption that commercial logging catalyzes the deforestation process An optimal control model is constructed to assess the principal issue The conceptual analysis advances previous deforestation studies by solving for the forest clearing function considering the role of capital and foreign capital demand and also specifying a measure of financial distress to assess the role of debt in deforestation in a broader context These considerations are aimed at a conceptual understanding of why tropical country's opt to liquidate forest resources

The results indicate that although foreign asset availability new foreign debt issuances financial distress from foreign debt, and newly issued domestic credit

could have potentially deleterious effects on tropical moist forests the effects are complex and unclear in the direction of influence Other variables with links to foreign asset needs such as the aggregate volume of wood removed and aggregate import demand unconditionally exhibit depletive effects on forest areas On the other hand variables such as national income (output) the growth rate of national income forest product export supply and profits from the forest product trade exhibit conditional influences on the forest area industrially logged Their influences are a function of the sign of the marginal propensity to obtain income via industrial logging Like previous studies the model does not state conclusively that the international timber trade has direct influence on the forest area commercially cleared

CHAPTER 5
CASE STUDY

The ideas presented in the conceptual model can best be illustrated by examining a specific case. Ghana. This chapter provides a general description of the geography and economic climate of Ghana after independence. Ghanaian forestry actors and Ghanaian forest products trade. The chapter closes with a statement of justification for Ghana as the choice for empirical investigation.

Ghana

Geography and Political System

Ghana, a former British colony, is a low-income developing country located on the west coast of Africa, flanked by Côte D'Ivoire and Togo to the west and east and bordered by Burkina Faso to the north. The southern border provides access to the Atlantic ocean. Its total land area, measuring 238,537 square kilometers, currently supports 16.63 million people. Climatologically Ghana is classified as tropical, with temperatures ranging between 23-31°C in the hot months and 22-27°C in the cool months. English is the official language, however Ewe, Fante, Ga, Hausa, Twi, Nzima and Dagbani represent an array of local dialects.

Ghana gained independence from British rule on March 6 1957 and has since endured nine changes in government, several military coups and not surprisingly sundry constitutional amendments Today Ghana is a multi-party democracy vesting executive power in a president elected by universal suffrage every four years Like the United States an elected president can only serve two four year terms however Ghana s history demonstrates that constitutional changes are common occurrences due to changes in political philosophies

The Economy: A Bird's-Eye View

Ghana is best categorized as an agricultural and natural resource economy It is well endowed with a broad range of natural resources such as arable land, forests and sizable deposits of gold diamonds bauxite and manganese. Additionally with a sizable endowment of water resources Ghana has considerable potential for hydroelectric power With its comparative advantage in natural resources Ghana depends to a high degree on primary (agricultural as well as mineral) production and exports Exports of cocoa gold and timber account for the bulk of total merchandise exports, with respective shares of 43% 24% and 11% in 1990 (Kapur et al 1991)

This agricultural and resource economy supports its population with an estimated per capita gross domestic product (GDP) of US$400 in 1995 (EIU 1996) Agriculture forestry and fishing in sum accounted for 40-45% of GDP and employed about two thirds of the labor force in 1995 Ghana is among the world's

largest producers and exporters of cocoa ranking third behind Côte d'Ivoire and Brazil Services comprise the second largest sector in the economy accounting for a growing share in real GDP (over 40 percent in 1994) The remaining share of output is accounted for by a relatively diverse and well developed industrial sector when compared with other West African economies

The Ghanaian economy performed poorly over the 1970-1983 period This fourteen year era witnessed declining and negative growth rates in output a significant decreases in per capita income (approximately 30%) propelling a Ghanaian brain drain increasing balance of payments deficit declining and non-existent stocks of foreign reserves and an accumulation of external payments arrears of about US$580 million by the end of 1982 (Kapur et al) This deteriorating economic condition is an outcome of several influences inappropriate domestic policies external shocks (droughts rising energy costs and declining terms of trade), large fiscal deficits that were monetized causing inflationary pressures and over valued exchange rates and heavy government interventions through price distribution import controls as well as a massive expansion of the public sector through the establishment of a large number of state operated enterprises (Kapur et al) These economic distortions minimized incentives to produce save and invest in the Ghanaian economy Creditors confidence in the economy fell drastically The result was huge foreign exchange shortages imported goods shortages growing parallel markets deteriorating capital stocks

drastic reductions in export earnings and evaporated external financing from bilateral sources

This protracted poor performance influenced the Ghanaian government to launch the Economic Recovery Program (ERP) in 1983. The primary objective of the program is to improve the economic performance of the Ghanaian economy. To date the program has been moderately successful in meeting its objectives however these achievements came at a cost. The enactment of the ERP in 1983 is a recognition of Ghana's need for increased availability of foreign capital to revive, promote and maintain the health and vitality of the economy (EIU 1996, ISSER 1993).

The goals of revitalizing earnings from the agricultural, forestry, manufacturing and service sectors could only be met through monetary and fiscal reform. Monetary reforms under the ERP included (a) curbing the rapid growth in money supply to check inflationary pressures and pave the way for the economy's return to positive real interest rates, (b) explicit refusal to monetize government deficits, (c) increased reliance on market based instruments for monetary policy and (d) stabilization of the economy through monetary discipline. Additionally, the foreign exchange market moved from a managed official foreign exchange market with a burgeoning parallel foreign exchange market to a liberalized market based on economic fundamentals and supply and demand. Fiscal reform included as a primary goal the restoration of fiscal discipline by controlling the rate of growth of government expenditure. It was recognized that less government management of

the economy was a necessary reform. This is manifest through privatization of many state owned enterprises, elimination of costly administrative controls in the allocation of foreign exchange, explicit and timely settlement of debt payment arrears, and promotion of trade liberalization through the easing and elimination of controls on trade.

The benefits of the outward promotion of monetary and fiscal reform include enhanced creditworthiness and increased foreign capital flows into Ghana through foreign direct investment and increased foreign investor activity in the Ghanaian stock market. Enhanced creditworthiness brought increased support by donor agencies and creditors, including the World Bank and the IMF. The Institute of Statistics, Social and Economic Research (ISSER) notes that "total external debt as a proportion of GNP increased from 65.7 percent in 1990 to 66.9 percent in 1991. However, as a result of increasing export receipts and an expanding economy, the debt burden continues to ease"(ISSER 1993, p.72). This increased dependance on foreign debt as a source of financing domestic economic growth leads ISSER to remark that "the high dependence of the economy on external sources of financing, as shown by debt as a ratio of GDP, puts the growth process in a potentially precarious situation. In order to reduce dependance on external sources of financing, Ghana should intensify the strategy of diversifying its foreign exchange earnings." (p. 74). Efforts to intensify the strategy of diversifying foreign exchange earnings could potentially compromise Ghana's environment through

unmitigated use of primary resources to generate foreign earnings in a milieu of limited wealth alternatives

While wood removal from Ghana's forests was level environmental degradation prior to ERP was increasing, moving in tandem with the deteriorating economic conditions However these declining environmental conditions did not taper off during the early stages of the ERP Evidence shows that economic growth and development by way of the revitalization of agriculture forestry mining and the manufacturing industry imposed considerable environmental degradation cost on the Ghanaian economy (ISSER, 1992) Annual environmental degradation cost due to agriculture is estimated at US$65 5 million while forestry accounts for a cost of US$33 4 million Opportunity costs due to the mining and manufacturing sectors under the ERP initiative are not available However qualitative evidence suggests mining's impact on the environment can be assessed in terms of its impact on land air and water in the mining areas of the country and manufacturing's impact can be qualitatively assessed through visible changes in environmental quality resulting from increasing levels of industrial pollution (atmospheric water and solid waste) (ISSER 1993)

Aggressive promotion of the ERP has implications for Ghana's forest stock. Ghana's forests cover over one-third of the total land area however not all forests are suitable for commercial exploitation (EIU 1996) Commercial forestry concentrated in southwestern Ghana was the fourth largest foreign exchange earner in 1995 with US$190 million in earnings According to EIU the revitalization

of the forestry sector under the ERP has been successful in raising foreign exchange earnings but the revitalized program and Ghana's need to export has contributed to the depletion of forest reserves. The closed forest zone of Ghana occupies 8.2 million hectares of land of which 1.7 million hectares (7% of Ghana's total area) has been reserved (ISSER, 1993). The remaining 6.5 million hectares was deforested at an estimated rate of 2% annually based on experience during the 1980s (EIU, 1996). The asymmetry between economic development and environmental preservation in the developing country context is manifest in the following EIU statement:

> The [Ghanaian] government has had to make difficult choices between preservation and the need for hard [foreign] currency. It banned exports of 16 species of log in 1980 and has since extended the list. However, economic necessity has shelved plans to phase out log and lumber exports altogether. The current strategy is a package of incentives and penalties to encourage exporters to increase value added. Although there are signs that value added has recently increased, lack of [foreign] funds, managerial skills, technical expertise and marketing facilities remain significant constraints (EIU, 1996, p. 10).

Clearly the need for foreign reserves in a scarce export resource environment constrains the choices of Ghanaian policy makers and limits well intentioned conservation practices of Ghanaians.

Ghanaian Forestry

Institutions in Ghanaian Forestry

The majority of Ghana en logg ng is performed by domestic companies (EIU 1996) These companies rely on the timber Export Development Board for the marketing and pricing of produced forest products Concession contracts are awarded and monitored by the Forest Products Inspection Bureau This agency is also responsible for the maintenance of forest product quality standards and grading forest products and also acts as a guard against illegal industry transactions In recent years financing has strengthened both organizations however both remain substantially under-funded (EIU 1996) Typically available cash has gone into forestry management, research and equipment for logging sawmilling, and manufacturing

Forest Products Production

Ghanaian aggregate wood production (Q) in roundwood equivalents demonstrates a positive trend over the 1967 - 1994 period (Figure 5 1) Production rose from a level of 8 928 thousand cubic meters (cum) in 1967 to a level of 22 626 thousand cum in 1994 Only in 1991 was there a marked fall in aggregate wood production (production fell from 14 310 thousand cum in 1990 to 12 379 thousand cum in 1991) However in 1992 production recovered to post a 32% increase over

1991 production levels (production equaled 16 300 thousand cum in 1992)

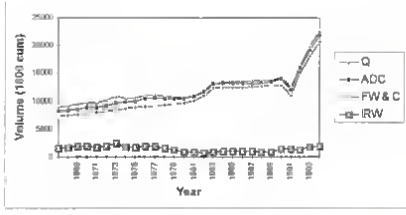

Figure 5 1– Ghana Wood Production 1967 - 1994

Domestic uses comprised the majority of Ghanaian aggregate wood production over the 1967 - 1994 period Apparent domestic consumption (ADC) defined as aggregate wood consumption net of exports and excluding imports of wood products is a major share of aggregate wood production (see Figure 5 1) Wood for domestic energy uses (FW&C) was the primary reason for wood extraction as demonstrated by Figure 5 1 The figure also shows that the volume of logs industrially extracted (IRW) is a small share of aggregate wood production over the time period Industrial roundwood extraction accounts for approximately 12 67% of Ghanaian aggregate wood production over this period

In addition to producing raw logs Ghana engages in value added wood production albeit small Three commodities account for Ghana's industrial wood production sawnwood, veneer sheets and plywood (Figure 5.2) Of these three commodities sawnwood is by far the most produced Sawnwood production (SWD) shows three trends over the sample period From 1967 to 1977 production increased from 220 1 thousand cum to 585 thousand cum From 1977 onwards production fell to a period low of 215 thousand cum in 1982 Since 1982 production has steadily increased to a level of 562 thousand cum in 1994

Figure 5 2– Ghana Value Added Wood Production 1967 1994

Plywood and veneer sheet production (PWD and VSH respectively) do not demonstrate similar levels of production and variability as sawnwood (Figure 5.2). Plywood production consistently exceeded veneer sheet production from 1967 to 1984. Since then veneer sheet production has slightly exceeded plywood production. All three commodities are a small share of Ghana's wood production and plywood and veneer sheets are an even smaller share.

Ghanaian Wood Exports and Revenue

Total wood exports (TXFP) declined from 1967 to 1982 (Figure 5.3). Wood exports demonstrate a positive trend from the low up to the end of the period, 1994. Although wood export levels rose steadily from 1982, they lag earlier levels.

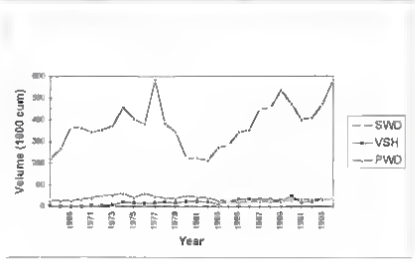

Figure 5.3– Ghana Wood Exports 1967 - 1994

Industrial roundwood comprises the majority of wood exports followed by sawnwood veneer sheet and plywood exports (XIRW XSWD XVSH and XPWD respectively) All four categories of wood exports achieved period lows between 1980 and 1984 and have steadily recovered up to 1994

A view of Ghanaian revenue obtained from forest product exports (Figure 5 4) reveals that industrial roundwood exports (VIRWD) and sawnwood exports (VSWD) have switched in importance of foreign exchange earning power since the period production lows demonstrated in Figure 5 3 Also clear is the relatively low prominence of plywood (VPWD) and veneer sheet (VVSH) exports in foreign exchange earnings power Aggregate revenues from forest product exports (VFPEX) increased from $US 29 5 million in 1967 to a high of $US 123 9 million in 1973 declined drastically to a period low of $US 11 18 million in 1982 and has since recovered to a period high of $US 229 21 million in 1994 (Figure 5 4) Note that industrial roundwood exports assumed the lions share of Ghanaian forest product export revenue prior to 1979 However since then sawnwood exports have exceeded industrial roundwood exports in foreign exchange earnings power Two things potentially account for the change a change in the Ghanaian government's policy or alternatively a change in the global institutional environment

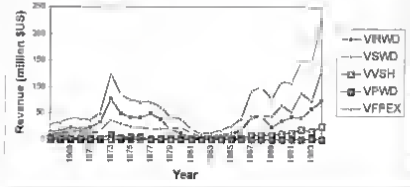

Figure 5 4– Ghana Forest Product Export Revenue

The Ghanaian government s ban on primary log exports created incentives to increase the value of Ghana's forest product exports on the world market This change in policy represents an effort to get more value (foreign exchange) for less production and preserve Ghana's forest stock. The global community's change in attitude towards forests and forest ecological systems might have affected the characteristic of Ghanaian exports by restricting the importation of raw logs via bans or tariffs and rewarding the production of higher-value wood products This institutional shift reflects the global community's desire to minimize industrial logging's role in primary forest destruction Both scenarios present interesting cases to tested empirically in chapter 8

The years 1980 through 1984 were difficult times for Ghanaian wood manufacturing and export (Figure 5.2 - 5.4). These years coincided with the trough of Ghanaian economic decline and the initiation of the economic recovery program (ERP). Also, these years coincided with the Latin American debt crisis and the onset of tight international financial markets. As is shown in chapter 6, Ghana moved from an economy characterized by low financial stress to one of high financial distress in 1981 and after.

In 1982 the Mexican government's response to increasing cost of borrowed foreign funds, declining economic growth, and increasing stress from foreign debt was to default on foreign debt repayments. The Mexican action changed the global financial environment open to developing countries by increasing lender's default risk premium. Consequently, this structural change in global lending had repercussions in the Ghanaian economy. All these factors are important in assessing the relationship between forest products trade, debt, foreign assets availability, and tropical forest depletion. The next chapter begins the empirical process by specifying an econometric model.

Justification

Ghana is an ideal case study for several reasons. Firstly, it is located in the tropics, and is one of few West African countries with tracts of virgin forests remaining despite years of commercial forest exploitation. Secondly, Ghana adopted explicit domestic policies in the late nineteen eighties to mitigate

environmental damages. An explicit objective of the economic reform program was to curtail destructive forest production practices. Consequently the export of raw logs was banned (1979) and forest exploitation slowed. However this was later repealed due to difficult financial repercussions. Lastly, African countries have received sparse attention in the literature on deforestation in general and the economic literature on tropical deforestation in particular. This study could potentially stimulate renewed focus on deforestation issues in the West African geographic region.

CHAPTER 6
ECONOMETRIC MODEL

This study is an investigation of the interface between national foreign reserve availability and tropical forest depletion using Ghana as a case study (see Chapter 5). It employs a partial analysis of tropical deforestation by concentrating analysis on the forest area cleared by industrial logging operations. Chapter 4 presented the conceptual model of trade and foreign asset influences on the area industrially logged. The conceptual model is used as a heuristic device for specification of the empirical model. Therefore the present chapter presents the econometric model of trade and foreign asset influences on the forest area industrially logged.

Financial Distress

An objective of this thesis is to assess the role of debt. As discussed in Chapter 3, the role of debt in the deforestation process has been explored by several authors (Kahn and McDonald (1985), Capistrano (1990) and Capistrano and Kiker (1995)) with differing conclusions. While this study makes an additional attempt at assessing the role of foreign debt in the deforestation process, it distinguishes itself from previous studies in two ways. First, it explores the role of

newly acquired foreign debt New foreign loans represent a form of foreign capital financing that increases a country's stock of reserves Constant access to foreign loans at low cost is assumed to be of priority to governments therefore the maintenance of good credit standing is important As such creation of foreign revenues from exports is essential to meeting principal and interest payments in the short term thus increasing a government s incentive to give logging concessions

Second the study deviates from previous works by considering the total performance of old and new debt It does so by constructing a latent variable index financial distress which measures the degree to which a particular country is financially challenged and burdened by current liabilities of principal and interest payments on foreign loans Financial distress is deemed a superior indicator of debt's role in the deforestation process because it considers the costs and benefits of foreign debt to the country under consideration The index is created from measures of profitability solvency and liquidity to indicate whether loaned funds are performing or under-performing The index facilitates defining a financially unstressed or distressed economy It is expected that a country under great financial distress will liquidate forest resources ostensibly to generate foreign asset earnings from forest product exports to meet foreign debt obligations and essential import requirements

Constructing and Estimating Financial Distress

The latent variable financial distress was estimated using confirmatory factor analysis (Bollen 1989) FS is constructed from four economic indicators import availability profitability the debt ratio and the debt service ratio Seale et al (1997) explain that one way a country can meet its financial requirements s through new borrowing or current growth They borrow Dornbusch s (1983) concept of import availability which is equal to exports plus "new money" minus debt service to construct the variable The level of import ava lability can be a constraint on growth as "new money" from commercial financial sources falls below debt service payments export earnings are available for debt servicing but not for purchasing imports Thus because imports are limited so is economic growth (Seale et al 1997) Profitability is defined as the growth rate in gross domestic product net of the real interest rate

The liability portion of financial flow is measured by the remaining two variables The debt ratio is the total external debt outstanding divided by gross domest c product it indicates the portion of gross domestic product required to completely retire external debt. The debt service ratio is interest payments plus principal payments divided by total export revenues it indicates the proportion of new cash flow requ red to retire total outstanding debt

Using these indicators the basic latent variable model can be written as

$$X = \beta FS + \delta \qquad (5.1)$$

where

X is a vector of observed indicators of financial stress (IA, PY, DR, DSR) where

IA import availability

PY profitability

DR debt ratio

DSR debt service ratio

FS is a latent (or unobservable) variable measuring financial distress from foreign debt

δ is a vector of error terms

and

β is a vector of factor loadings which represent the effect of each variable on financial distress

To estimate the factor loadings, the factor analysis procedure calculates the sample covariance matrix ($\hat{\Sigma}$) from the data of the indicators normalized to means of zero and standard deviations of one. This is done by subtracting the vector mean from each observation and dividing the result by the vector's standard deviation such that

$$\hat{x} = (x - \bar{x})/\sigma \qquad (6.2)$$

where $\hat{x}$ is the vector of normalized observations, and σ is the standard deviation. When the observed variables are normalized

$$\hat{\Sigma} = (\hat{x}'\hat{x})/n \qquad (6.3)$$

because x'x = 0 Consequently the sample covariance matrix ($\hat{\Sigma}$) is equal to the sample correlation matrix

From equation (6 1)

$$x = E[\beta FS + \delta] = \beta E[FS] + E[\delta] \quad (6\ 4)$$

By assuming that the latent variable is uncorrelated with the residual δ it can be shown that $E[FS] = 0$ and $E(\delta) = 0$ Therefore

$$\hat{\Sigma} = XX' \quad (6\ 5)$$

Substituting equation (6 1) into equation (6 5)

$$\hat{\Sigma} = (\beta FS + \delta)(\beta FS + \delta) = (\beta FS + \delta)(FS\beta + \delta) = \beta FSFS'\beta' + \delta\delta' \quad (6\ 6)$$

In this way the variance matrix is decomposed into a 'systematic' component ($\beta FSFS'\beta$) and a "nonsystematic' component ($\delta\delta'$) Note that $FSFS = F$ which is the variance of the latent variable and $\delta\delta' = \Theta$ the "nonsystematic' component which accounts for the variance not explained by the common variation of common factor

If the vector of observed indicators of financial distress (x) has a mean of zero its covariance matrix can be derived as

$$\hat{\Sigma} = \beta F\beta + \Theta \quad (6\ 7)$$

where $\hat{\Sigma}$ is the covariance matrix between indicators F is the variance of the latent variable of financial distress and Θ is the variance of idiosyncratic errors or errors not correlated with the latent variable [$E(\delta\ \delta)$] By normalizing the vector of observed indicators the factor loadings will also be normalized so that the variance of the latent variable is unity ($F=1$) Therefore, the measure of financial distress will

have a mean of zero and a variance of one. The financial distress measure can then be interpreted as deviations above and below the mean and represents changes in financial distress levels from the mean level.

To estimate the factor loadings the maximum likelihood approach is employed. The following likelihood function is maximized:

$$L = -(T/2)\log|\beta F \beta' + \Theta| - (T/2)\,tr\,[\hat{\Sigma}(\beta F \beta' + \Theta)^{-1}] \qquad (6.6)$$

with respect to β. Since the latent variable of financial distress is normalized to have a variance of 1, this function is simplified to:

$$L = -(T/2)\log|\beta\beta' + \Theta| - (T/2)\,tr\,[\hat{\Sigma}(\beta\beta' + \Theta)^{-1}] \qquad (6.9)$$

where $\hat{\Sigma}$ is the sample variance matrix, T is the number of observations, and tr denotes the trace. This is the likelihood function for confirmatory factor analysis specified by Bollen (1989). This function yields parameter estimates with desirable asymptotic properties.

Results

The estimated factor loadings from the analysis are (IA, -0.72006; PY, -0.0509; DR, 0.86536; DSR, 0.99257). The signs are as expected. Improvements in import availability, IA, and profitability, PY, should signal improving financial conditions; therefore negative values for both variables are valid. As the burdens of foreign debt increase it should be expected that financial pressures would increase. Thus the positive values for the debt ratio, DR, and the debt service ratio, DSR, are consistent with expectations.

Using these factor loadings the financial stress FS variable is constructed based on the generalized least squares method proposed by Bartlett (1938) and employed by Gottret (1990) and Seale and Moss (1997) These estimates provide a FS observation for each time period

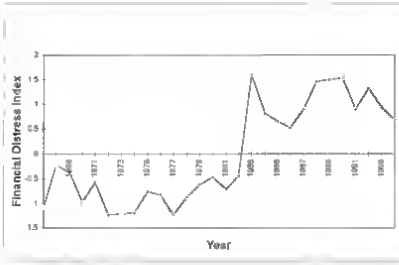

Figure 6.1– Ghana Index of Financial Distress 1967 1994

Ghana was under low financial distress relative to its external position during the 1967 1982 period (Figura 6 1) However, around the time of the Latin American debt crisis Ghana experienced increasing financial distress from foreign debt. From 1984 to the end of the sample period there is evidence of a downward trend in financial distress however the index remains positive indicating continued financial distress from foreign debt Seale and Moss (1997) calculated financial stress

indexes for four Central and South American countries (Costa Rica Guatemala Brazil and Venezuela) whose paths over time are similar to Ghana s

In 1983 Ghana s financial distress index increased drastically became positive and remained positive for the duration of the sample period (1984 1994) The Ghanaian government addressed the d stressing economic times of the country by initiating the 1983 Economic Recovery Program (ERP) It seems that the global community reacted favorably to the reforms since from 1986 to 1992 Ghana received s gnificant foreign cash flows from the International Monetary Fund (IMF) The increase in financial distress initiation of the ERP and the increased capital flows from the IMF suggest a macro-scale phenomenon worth exploring in the context of the current model A dummy variable capturing this phenomenon is used to assess the effect of the ERP on forest clearing This is modeled through aggregate wood extraction From the temporal distribution of the FS index it seems that FS should be modeled as e quadratic or cubic function

The Empirical Model

The forest clearing model is est-mated in logarithms to account for the non-linear relat onships suggested by the conceptual model of chapter 4 Recall that the relationships describing forest clearing are inherently nonlinear therefore it was assumed that the data from such e process is of a nonlinear nature Additionally e model in logarithmic form facilitates interpretation of parameter estimates since derivatives represent elasticities

The conceptual model of chapter 4 is used to heuristically characterize the specified econometric model the concession forest area clearing model (CFACM) The identification of the timber trade s role in tropical deforestation is important. A fundamental supposition of this study is that while the timber trade might be a minor part of tropical country's foreign exchange earnings overall it is likely to play a key role in opening previously inaccessible forested lands

The timber trade s contribution to tropical forest depletion is assessed by broadening the scope of the trade to include the trade in forest based products (i e timber and log derivative products) Since it is the trade in forest based products that is potentially a significant contributor to tropical deforestation a wider scope is necessary Specific products to be considered are roundwood sawnwood veneer sheets and plywood

The character of the model reflects concepts explored in chapter 4 and variables proven to have significant influence on tropical forest depletion in previous studies Following Seale and Moss (1997) tropical forest depletion will be estimated conditioned on a latent variable financial distress That is the effect of financial stress on the area industrially logged will be assessed through the parameter on income in the forest clearing equation and the wood extraction equation Therefore depending on the level of financial distress of the economy forest clearing may occur at an increased or decreased rate Higher financially stressed countries will experience higher rates of area cleared than lower financially

stressed countries Note however that this might not be the case but at least the sign is expected to be in that direction The model in log-linear form is

$$\ln(HA) = \beta_{10} + \beta_{11} \ln(vqx) + \beta_{12} (\ln(vqx) \ln(Q_j)) + \beta_{13} \ln(Y) + \beta_{14} (\ln(Y))^2 + \beta_{15} \ln(A) + \beta_{16} \ln(M) + \beta_{17} GrY + e_1 \quad (6\ 10)$$

$$\beta_{13} = \tau_0 + \Sigma_i \tau_{1+i} FS^{1+i} \qquad i = 0\ 1, 2 \quad (6\ 11)$$

$$\ln(A) = \beta_{20} + \beta_{21} RXR + \beta_{22} \ln(M) + \beta_{23} \ln(Y) + \beta_{24} \ln(ND) + e_2 \quad (6\ 12)$$

$$\ln(Q_j) = \beta_{30} + \beta_{31} \ln(Y) + \beta_{32} (\ln(Y))^2 + \beta_{33} \ln(vqx) + \beta_{34} (\ln(vqx))^2 + \beta_{35} \ln(A) + \beta_{36} ERP + e_3 \quad (6\ 13)$$

$$\beta_{31} = \eta_0 + \Sigma_i \eta_{1+i} FS^{1+i} \qquad i = 0\ 1, 2 \quad (6\ 14)$$

$$\ln(vqx) = \beta_{40} + \beta_{41} \ln(\rho_{hp} / \rho_{WPI}) + \beta_{42} \ln(W) + \beta_{45} RXR + \beta_{44} GFR + e_4 \quad (6\ 15)$$

where

HA = FI / AAC

and variables are defined as

HA forest area industrially logged in 1000 hectares

FI total wood removed from natural forests for industrial use in 1000 cubic meters of roundwood equivalent

AAC gross annual allowable cut–the average volume of marketable wood in roundwood equivalent per hectare of undisturbed closed broadleaved forest in cubic meters per hectare

GrY growth rate of real gross national income (calculated as $\Delta Y/Y$)

M aggregate import demand constant 1987 US$

Q_j total volume of roundwood extracted in 1000 cum j = TQ ADC NIW

where

Q_{TRE} is aggregate volume of roundwood produced

Q_{ADC} is apparent domestic consumption of roundwood

Q_{NIW} is other logged roundwood. Total roundwood net of industrially logged round wood (fuelwood, charcoal, etc)

vqx total value of forest products exported, in million $US (1987=100)

p_{fp} received forest products export price index

p_{WFP} world export price index for forest products

Y real gross national income (GNI), in million $US

A Total foreign reserves, in million $US

ERP dummy shifter, 0 or 1

ND New debt disbursement, in million $US

RXR real exchange rate, in percent

FS financial distress index

W index for real OECD income, in billion $US

GFR dummy shifter, 0 or 1

Parameters are represented by βs, τs and ηs and random error terms are designated by εs. The endogenous variables of the CFACM are A, Q_j, vqx and HA. All variables not identified as endogenous are considered exogenous.

The specification of the forest area industrially logged equation (6.10) is consistent with the conceptual model. The assumption that the forest product trade

catalyzes the deforestation process is captured by the first two variables (vqx and vqx^*Q_t), and the inclusion of gross national income the growth rate of gross national income financial distress and aggregate import demand are consistent with the conceptual model An indicator of long-term national goverment objective is needed to assess the impact of growth on forest resource use The growth rate of gross national income re[resents a good proxy The inclusion of fore gn assets is new Chapter 4 hypothesized that the inclusion of foreign assets in the forest cleanng function is inappropnate Therefore its inclusion is e test of the hypothesis Since new debt disbursement (ND) and financial distress (FS) are highly collinear. new debt is dropped from the forest area industrially logged equation and the wood extraction equation and the financial distress variable retained

Equation (6 12) and equation (6 13) ere also consistent with the conceptual model The inclusion of e dummy variable (ERP) in equation (6 13) for the economic reform program is necessary for evaluation of the program s effects on the forest area industrially logged Additionally, financial distress is included in (6.13) since income is a variable in the equation. This maintains a consistency that is missing from the theoretical framework.

Equation (6 15) is a theoretically consistent export supply equation It is augmented by a dummy variable (GFR) to evaluate the impact of the 1979 export ban on forest product export supply and also its effect on cleared forest area

In the following discuss on of the assumptions underlying the model t and s will represent individual time periods and T represents terminal time

The unobservable random error vectors e_1, e_2, e_3, e_4 are generated by a stationary multivariate process satisfying the following assumptions

1 All disturbances have a zero mean

$$E[e_{it}] = 0 \qquad i = 1\,2\,3\,4 \qquad t = 1\,2, \quad T$$

2 In a given equation the disturbance variance is constant over time but each equation can have a different variance

$$var(e_{1t}) = E[e_{1t}\, e_{1t}] = \sigma_1^{\,2} = \sigma_{11}$$

$$var(e_{2t}) = E[e_{2t}\, e_{2t}] = \sigma_2^{\,2} = \sigma_{22}$$

$$var(e_{3t}) = E[e_{3t}\, e_{3t}] = \sigma_3^{\,2} = \sigma_{33}$$

$$var(e_{4t}) = E[e_{4t}\, e_{4t}] = \sigma_4^{\,2} = \sigma_{44}$$

The notation σ_1 is just an alternative way of writing $\sigma_1^{\,2}$

3 Two disturbances in different equations but corresponding to the same time period are correlated (contemporaneous correlation)

$$covar(e_{it}\, e_{jt}) = E[e_{it}\, e_{jt}] = \sigma_{ij} \qquad i, j = 1\,2\,3\,4$$

4 Disturbances in different time periods whether they are in the same equation or not are uncorrelated (autocorrelation does not exist)

$$covar(e_{it}\, e_{js}) = E[e_{it}\, e_{js}] = 0 \qquad \text{for } t \neq s \text{ and } i, j = 1\,2\,3\,4$$

The aforementioned can be written more compactly as

$$E[e_t] = 0 \qquad \text{for} \qquad t = 1\,2\,3\,4$$

and

$$E[e_t e_t'] = \sigma_{ij} I_T \qquad \text{for} \qquad i, j = 1\,2\,3\,4$$

which implies that if $e' = (e_1\ e'_2\ e'_3\ e'_4)$ then

$$E[ee'] = \Sigma \otimes I_T$$

Thus the CFACM assumes that

$$e \sim N(0\ \Sigma \otimes I_T)$$

indicating that the random error vector in each equation is distributed normally with mean zero and variance sigma. The unknown contemporaneous covariance matrix Σ is a (4x4) symmetric and positive semi-definite matrix.

Estimation Procedure

The concession forest area clearing model is estimated using simultaneous equation statistical techniques. The system is estimated in two stages. The first stage involves the estimation of the factor loadings of financial stress (FS) as previously discussed. The FS variable is used as an exogenous variable in the estimation of influences on the area industrially logged.

The second stage of the analysis will involve the estimation of the CFACM via three stage least squares (3sls). The preferred method of estimation is 3sls since the equations in the CFACM are all over-identified according to the rank and order conditions of identification. Judge et al. (1988) demonstrate that when all equations in a system are over identified the three-stage least squares estimator is asymptotically more efficient than the two-stage least squares estimator applied to all the structural equations in the system. The relative inefficiency of the two-

stage least squares estimator arises because it ignores the information contained in the off-diagonal elements of the contemporaneous covariance matrix, Σ.

The concession forest area clearing model is conditioned on the estimation of financial distress. For each Q_j a complete model will be tested against a reduced model to determine the functional form for financial distress. Therefore six specifications of the CFACM are estimated. The quasi-likelihood ratio test suggested by Gallant and Jorgenson (1979) is used to test the restricted simultaneous equation system versus the unrestricted simultaneous equation system. The test is based on the minimum distance function E. The test statistic is approximately chi-square (χ^2) and is equal to $n(E_0 - E_1)$ where E_0 is the E statistic of the restricted model, E_1 of the unrestricted model, and n is the number of observations.

CHAPTER 7
DATA

This chapter identifies data sources and defines and describes the nature and characteristics of the data used to estimate the econometric model presented in Chapter 6. The chapter is organized as follows. First data sources are identified followed by descriptions of data characteristics and the methods employed in creating sundry data sets.

Data Sources

The raw data used in this study were obtained from several sources. The World Bank's World Data on CD-ROM was the main source of data on gross national income, gross domestic product, and gross national product at market (nominal) prices, merchandise imports, all price indices, Ghanaian/US nominal exchange rates, total reserves minus gold, OECD GDP at market (nominal) prices, and long-term debt, debt disbursements, principal payments, interest payments, and external debt.

Foreign exchange and OECD world prices (in export unit values) were obtained from the International Monetary Fund's International Financial Statistics Yearbook.

Forestry production trade and export revenue data came from the Food and Agriculture Organization's (FAO) Web Site. The data were compared with several publications of the FAO Yearbook of Forest Products for consistency of data reporting. Where a discrepancy in data reporting occurred the Web Site's figure was the datum of choice. Data on forest productivity (gross annual allowable cut (AAC)) were obtained from the Food and Agriculture Organization and United Nations Environment Programme's (FAO/UNEP 1981) Tropical Forest Resources Assessment Project Reports.

Data Characteristics

Indicator of the Forest Area Industrially Logged

The area of tropical moist forest industrially logged, HA, was used as the dependent variable in the commercial forest clearing equation. The forest clearing equation was modeled as a function of forest product export supply, aggregate wood recovery, gross national income, new debt disbursement, growth in gross national income and aggregate import demand.

The construction of the forest clearing variable follows the conceptual development of Capistrano (1990). Capistrano defines the equivalent average annual supply of legally extractible timber per unit i as

$$s_i(P_{fm}Z) = Q_i(P_{fm}Z) / T_i(P_Z)$$

where a unit is defined as a hectare of a particular site class [1] of forest land. In this supply definition Q (P fm Z) is the optimal volume of wood produced from a unit area of forest land which is a function of price P, forest management effort, fm, and a summary descriptor of macroeconomic conditions Z. T_i(P Z) is the optimal growing period of trees in the forest and it is a function of price and the summary descriptor of macroeconomic conditions. The aggregate volume of legally extractible timber can be obtained by summing across all hectares H of each site class and across all site classes. This is characterized as

$$S(P\ fm,Z) = \Sigma_i H_i s_i (P\ fm\ Z)$$

It then becomes simple to derive the aggregate forest area commercially cleared as

$$H(P\ fm\ Z) = \Sigma_i H = S(P\ fm\ Z) / s$$

where s becomes the average commercial timber productivity per hectare and H(P fm,Z) is the total hectares of forest depleted by government-authorized logging.

Empirically Capistrano constructed H(P fm,Z) from aggregate timber extraction data and represented it as

$$HI = FI / VAC$$

where FI corresponds to S(P fm Z) and is defined as the total wood removed from natural forests for industrial use in 1000 cubic meters (cum) of roundwood equivalent, and VAC corresponds to s and is defined as the volume actually

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[1] Site class is a classification of forest land quality based on tree growth. It is used as a proxy measure for productive potential. See Hyde (1980), Leuschner (1984), Robinson (1988).

commercialized in cubic meters of roundwood equivalent per hectare. VAC is the average volume of marketable wood in roundwood equivalent obtained per hectare of undisturbed closed broad leaved forest.

This study approximates the forest area commercially cleared (in million hectares) by

$$HA = FI / AAC$$

where FI is similar to Capistrano's definition and the denominator of choice is AAC. The gross annual allowable cut. AAC is the average volume of marketable wood in roundwood equivalent obtained per hectare (cum/hectare) of intensively managed productive closed broad leaved forest.[2] In general AAC is equated with current annual yield per hectare. It is a market based definition of forest productivity and government policy will be based solely on wood species for which commercial demand exists. With improvements in forest management practices and forest health the AAC for a given area of forest increases as more species become economically valuable. AAC is preferred to Capistrano's VAC for two reasons. First, because the majority of Ghana's closed broad leaved forest is intensively managed (FAO 1981). Under this scenario the gross annual allowable cut (AAC) which in general is equated with current annual yield is the most

[2] The concept of intensive management as employed by the FAO/UNEP is restricted. It implies not only the strict and controlled application of harvesting regulations but also silvicultural treatments and protection against fires and diseases. These forests constitute the part of the permanent productive forest estate in a given country to which the concept of annual allowable cut' can be meaningfully applied.

theoretically consistent measure of forest productivity and the most appropriate concept of volume removed per hectare of forest. Second, Kummer and Turner (1994) note that because logging activity has been consistently under reported in the post-war period and because the annual allowable cuts are consistently larger than reported by Forest Management Bureau statistics on logging, the annual allowable cut more accurately reflects the amount of timber removed both legally and illegally. Although this study chooses AAC over VAC, Capistrano's choice is nonetheless justified on the basis that the global cross sectional study conducted warranted the use of VAC since it could not be justified that all tropical countries intensively managed their tropical broadleaved forests. A better measure is clearly available for Ghana.

Financial Distress and Foreign Debt(FS)

Proper assessment of debt's role in the forest clearing process must incorporate the costs and benefits of debt. Singular focus on solvency as an indicator of financial stress from foreign debt ignores the fact that a high solvency ratio through increased borrowing can be ominous, however, if the newly acquired money is productive and is manifest in high export growth or high gross national income growth, then it is possible that such a debtor will experience little financial distress from foreign debt (Seale and Moss, 1997). Thus it is prudent to consider other factors besides solvency to assess the influence of foreign debt on the forest area commercially cleared.

Chapter 4 reasoned conceptually that increased financial distress would have an adverse indirect influence on the forest area through increased industrial logging. This theoretical finding is assessed and tested via the parameters on gross national income in the commercial forest clearing equation and the wood extraction equation. It is expected that increased financial distress will have a positive effect on the marginal propensity to industrially clear forest areas for income and on the marginal propensity to extract wood for income. Consequently financial distress is expected to have an adverse effect on extant forests.

Price Indices

Several price indices are used in the empirical analysis. Forest product price indices are constructed for Ghana and the OECD using unit export values in US dollars per cubic meter (roundwood equivalents) and the export revenue share of four forest products (= industrial roundwood, sawnwood, veneer sheets and plywood). These commodities are the major forest product exports of Ghana. The OECD price index is preferred because the pattern of trade as regards Ghana's forest product exports has a northern characteristic. While Ghana-South trade exists its share in total exports does not significantly influence market price. These price indices are used as explanatory variables in the Ghanaian export supply equation.

Stone's method (Deaton and Muellbauer 1980) was used to construct forest product export price indexes for Ghana and the OECD. Mathemetically this index is expressed as

$$\ln P = \Sigma_i w_i \ln P_i \quad \text{where} \quad w_i = R_i / \Sigma_i R_i$$

where the loganthmic unit value prices are weighted according to w_i, the products' share in aggregate forest product export revenue, R_i. Both forest product prices were deflated by the world price index with 1990 as the base year.

Income

Several measures of national income are employed. The measures include real gross domestic product (GDP), gross national product (GNP) in current dollars and real gross national income (GNI). GNI is the domestic (Ghana) income variable of choice in the commercial forest area clearing system, real GDP is used for OECD income (W) in the forest products export supply equation, and Ghanaian GNP in current dollars is used in the construction of the financial distress latent variable.

Drawing on the income elasticity of environmental quality and on the work of Grossman and Krueger (1992) the conceptual chapter hypothesized that higher income is associated with greater forest clearing from commercial logging. Higher income increases demand for forest products thereby increasing the opportunity cost of keeping the forest unexploited. Hartmann (1976) cogently argues that if the pristine quality of the forest is a normal good, higher income could increase the

demand for forest preservation. Thus if the value of preservation demand is high enough it may be optimal not to liquidate the natural forest asset. Capistrano (1990) reasons that since higher income tends to both increase and reduce forest depletion its net effect on the forest stock is really an empirical question. Furthermore she reasons that financially stressed developing countries would view forest preservation as a luxury good therefore additional income would be used to satisfy unmet needs rather than to protect the forest. The study adopts Capistrano's line of reasoning and also argues that the forest stock is used to generate additional income.

Growth Rate in Income

This variable is used as a proxy for changes in the stage of development and as an explanatory variable in the forest clearing equation. While there is no theoretical basis for its inclusion it is believed that income growth comes from productivity increases in the manufacturing and service sectors or from increased revenue from the primary resource sectors. As an economy moves from less developed to more developed there is less dependence on the primary resource sector to spur national income and national product growth. Ghana's current stage of development is less developed but improving. Therefore currently it depends substantially on its primary resources to generate increases in foreign revenue and national income.

Dramatic increases in forest sector revenues contributes to increased revenues from the primary sector which has implications for the forest area commercially cleared. The expected sign on this variable is positive because in a financially stressed economy there is a negative correlation between income growth and environmental quality in the short term. As the economy demonstrates less dependence on the primary sector to generate foreign reserves in the long term the expected relationship between income growth and environmental quality becomes positive.

Merchandise Imports

The real value of merchandise imports was used as an exogenous financial variable in the forest clearing equation to explore the relationship between foreign reserve needs to finance imported goods and the extent of commercial forest clearing. It is expected that as the demand for imported goods increases a corresponding increase in commercially cleared forest areas follows (see chapter 4). The factor driving this relationship is Ghanaian demand for foreign reserves which is hypothesized to have an adverse effect on forested areas.

Total Foreign Reserves

The IMF definition of total reserves the sum of the countries reserves of foreign exchange special drawing rights (SDR position) and gold holdings is used as the dependent variable for the foreign capital demand equation. Ghana's

demand for foreign capital is modeled as a function of the real exchange rate aggregate import demand new debt disbursements and gross national income. Chapter 6 discusses how this variable is utilized to elicit its effect on the forest area commercially cleared. Briefly stated the relationship between a tropical country's stock of foreign reserves and the forest area industrially logged is expected to be negative.

The Real Exchange Rate

The real exchange rate is defined as

$$RXR = XR * (WPI / CPI)$$

where XR is the nominal exchange rate expressed in number of units of domestic currency per US dollar CPI is the consumer price index, the domestic currency deflator and an index of domestic inflation and WPI is the US wholesale price index the US dollar deflator reflecting US inflation. Note that the exchange rate is defined such that an increase indicates a nominal depreciation of the domestic currency. Also in the regressions this variable is deflated by 10 to reduce reduce the number of zeros following the decimal point.

Macroeconomic variables such as domestic and foreign money supplies real incomes interest rates price levels, and international balances all affect the real exchange rate (Dornbusch and Fisher 1987). Like most financial variables the real exchange rate is not immune to the effects of massive external borrowing which can lead to a depreciation in its value. Likewise increased productivity and greater

capital exports can have an opposite effect by appreciating the value of the currency New valuable resource discoveries resource devastation and expectations can autonomously change the real exchange rate

The real exchange rate plays an important role in resource allocation in developing countries When the real exchange rate appreciates or depreciates due to price movements or nominal exchange rate movements resources tend to move Currency appreciation lowers incentives for exportable goods production while encouraging imports leading to deficits greater financial stress from foreign debt and declining international reserves

Depreciation of the Ghanaian cedi relative to the US dollar is likely to have an indirect effect on the forest area commercially cleared The process of this effect is manifest in two forms Firstly Ghanaian products become relatively cheaper and thus more competitive on the world market therefore leading to an increase in forest product exports Additionally due to lower returns for its forest product exports Ghana finds itself exporting greater volumes of forest products to maintain previously high revenue levels during high price periods Thus price and revenue effects cause greater volumes of forest products to be exported which translates into greater forest areas industrially cleared This exchange rate effect is assessed and tested in the forest product export supply equation

Secondly real exchange rate depreciation leads to reduced levels of total foreign reserves which can be increased through greater volumes of forest product exports Again this translates into greater forest areas commercially logged

(cleared). The foreign capital reserve equation is used to assess and test the effect of the real exchange rate on reserve levels. Additionally, the indirect influence of depreciating real exchange rates on the forest area industrially logged is tested through its effect on Ghana's marginal propensity to clear forest areas via commercial logging.

Aggregate Roundwood Production

The total volume of roundwood extracted is used as the dependent variable in the aggregate roundwood extraction equation and as an explanatory variable in three forms in the forest clearing equation. The three forms of roundwood extraction are 1) aggregate roundwood extraction, 2) apparent domestic consumption of roundwood, and 3) aggregate roundwood net of industrially extracted roundwood (consumption of charcoal and fuelwood). Structurally, roundwood extraction is modeled as a function of gross national income, aggregate forest product export supply, and financial distress. It is hypothesized in chapter 4 that there is an a relation between roundwood extraction and the forest area industrially logged.

Quantity and Value of Forest Product Exports

Conceptually, the aggregate volume of forest products exported is the ideal measure for the dependent variable of the forest products export supply equation. Because mixed forest products are traded in the international market, a true

quantity of forest product traded is difficult to define Therefore empirically the aggregate volume of forest products exported is not an ideal measure Fortunately a good proxy which avoids the aggregation problem exists for the total volume of forest products exported The total revenue (value of forest product exports) earned from exporting forest products is used as the measure of the dependent variable in the export supply equation and also used as the measure of an explanatory variable in the wood extraction equation and the forest clearing equation Since money is a common unit of transaction for all goods it is possible to sum real balances across all forest products exported and obtain a meaningful measure in the aggregate

The export supply equation is modeled as a function of the ratio of price (see discussion of price indices in this chapter) received by Ghana and the world price (see discussion of price indices in this chapter), OECD income measured as real GDP and the Cedi/$US real exchange rate Chapter 4 argues that increased forest product exports are positively related to wood recovery and have an indirect adverse influence on the forest area commercially cleared Identical signs are expected from the empirical model Since total revenue is used as the proxy for volume of forest products exported the possibility of assessing the effect of increased export revenue on the forest area industrially logged clear

Dummy Variables

Two intangible events are assessed in this study. The economic reform program (ERP) of 1983 coincides with Ghana's financial distress index switching from negative to positive. It would seem that the ERP is a response to the imminent financial challenges confronting Ghana. In the context of the present work it is of interest to explore the effect of the resulting drastic change in the policy and financial environment on Ghanaian cleared forest area and aggregate wood extraction. Also the study assesses changes in the global community's attitude towards forests and forest ecological system contributions to global welfare. Beginning in 1979 log import bans were imposed by many OECD countries and external pressures induced many tropical countries to impose log export bans or taxes to deter the international trade of raw logs. Ostensibly these actions were intended to conserve tropical forests by curbing destructive logging practices. The impact of this global institutional shift is modeled in the Ghanaian export supply function through the OECD income term. Both events represent external institutional shifts which affected many developing countries in general and Ghana in particular.

CHAPTER 8
RESULTS AND DISCUSSION

Regression coefficient estimates and their standard errors are reported. Based on significant coefficient estimates, data means, and an estimated covariance matrix, marginal effects and total system elasticities are estimated for the Ghanaian forest area industrially logged (FAIL). These estimates are reported with standard errors, and significant estimates are indicated by asterisks in the tables of results. Additionally, total system elasticities are calculated at data points for FAIL and reported without standard errors. The chapter concludes with a summary.

Statistical Tests

Tests of significance were conducted at the 0.025, 0.05, and 0.10 levels. It is the general feeling of the author that all results and tests derived in the current work should be viewed generally as guides to inform the audience and the policy process. However, readers demanding greater rigor in testing have the option of ignoring variables with lower levels of significance.

The models were estimated with financial distress assuming the quadratic specification. The quadratic specification was chosen over the cubic specification

on the basis of the quasi-likelihood ratio test for two and three stage least squares developed by Gallant and Jorgenson (1979). The test is based on the principle that if an estimated function of the data is asymptotically normally distributed with a variance-covariance matrix which can be consistently estimated it is possible to construct a variable which is chi-square distributed from this function of the data. The vector of differences between the residuals under the null hypothesis (the quadratic specification is sufficient for representing the data) and the residuals under the alternative hypothesis (the cubic specification fits the data best) is the function of interest and has expectation of zero under the null. The model with the quadratic specification is nested within the model with the cubic specification. Therefore residuals from the model under the null should exceed residuals from the model under the alternate hypothesis making the test of the difference necessarily positive. The test is asymptotically chi-squared with degrees of freedom equal to the number of restrictions imposed that is the number of parameters in the second model minus the number of parameters in the first.

Regression Results

Results from the estimation of the four equation system are presented in Tables 8.1 through 8.4. Three definitions of extracted roundwood were used in the estimation of the system: total roundwood removed (TQ)[1] apparent domestic

[1]TQ is composed of exported and domestic forest products plus fuelwood and charcoal.

consumption of roundwood (ADC)[2] and total roundwood in the form of charcoal and fuelwood (NIW)[3]. All variables with the exception of rate variables (the real exchange rate RXR and the growth rate of gross national income (GrY) dummy variables (ERP and GFR) and the financial distress index (FS) are logarithmic. Therefore the general tendency is to interpret individual equation parameter estimates as elasticities. This is valid however in the case of the FAIL equation (6.10) and the wood extraction equation (6.13) elasticity estimates for forest product export supply (vrpx) and gross national income (GNI) are complex (involving greater than one parameter estimate). For these two equations all other parameter estimates related to logarithmic variables can be interpreted as partial elasticities. The forest product export supply equation (6.15) and the foreign asset equation (6.12) present no interpretational difficulties.

Two sets of system results are derived to elicit influences on FAIL. Firstly marginal system effects are derived for relevant variables. These derivations are useful in characterizing exogenous influences on FAIL. However because of differences in data measurement system marginal influences are not comparable across variables. To facilitate comparison across variables within FAIL total system elasticities are calculated at the data mean and at data points.

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[2]ADC is composed of domestic forest products plus fuelwood and charcoal.

[3]NIW is composed of fuelwood and charcoal.

Influences on the Forest Area Industrially Logged

Parameter estimates of the forest clearing equation are given in Table 8.1. The results indicate that the forest area industrially cleared was significantly (α=.05) effected by growth rate of gross national income (GrY) and the interaction between wood extraction (Q_i) and forest product exports (vqx). The elasticity estimate for forest product exports is not clear since it depends on its interaction with wood extraction. However, the assumption that forest product exports catalyze the deforestation process is partially supported by the positive sign on the export/extraction interaction term.

The growth rate in income is an indication of long-term government plans for national economic growth. In the models it also represents a quasi-direct effect on cleared forest area. It gives an indication of the direction of influence on cleared forest area (which is to increase it), however, the magnitude of the effect depends on the size of the forest area industrially cleared. The positive estimate confirms that forest resources are utilized to attain a higher Ghanaian standard of living. The result is not surprising since it is consistent with any country's economic behavior, developed or developing. Forest resources are threatened when national economic objectives are met through primary resource use void of stock preservation measures.

Table 8 1– 3sls Parameter Estimates (with Standard Errors) for Ghanaian Forest Area Industrially logged 1967-1994

Model with Q_i	=ln(TQ)	=ln(ADC)	=ln(NIW)
Dependent Variable	ln(HA)	ln(HA)	ln(HA)
Intercept	139 19 (155 19)	116 62 (171.28)	135.26 (189 98)
ln(vqx)	1 48* (0 86)	1 57* (0.94)	1 42* (0 93)
ln(vqx)*Q_i	0 18** (0 09)	0 19** (0 10)	0 18* (0 10)
ln(Y)	28.56 (39 53)	25 77 (46.81)	29.63 (46 53)
ln(Y)*FS	-0 81*** (0 005)	-0 81*** (0 005)	-0 82*** (0 005)
ln(Y)*FS^2	0 001 (0 005)	0 001 (0 005)	0 002 (0 005)
(ln(Y))^2	1 83 (2.34)	1 46 (2 42)	1 88 (2.41)
ln(A)	-0 14* (0 10)	-0 17* (0 11)	-0 16* (0 11)
ln(M)	0 19 (0 18)	0 15 (0.21)	0 18 (0 19)
GrY	0 01*** (0 004)	0 01*** (0 004)	0 01*** (0 004)

*s gnificant at α= 10, **significant at α= 05 ***significant at α= 025

HA. Forest area Industrially logged in 1000 hectares
Q Roundwood Classification (i=TQ ADC NIW)
qx. Volume Roundwood Exported in 1000 cum
ILW Industrially Extracted Roundwood in 1000 cum
TQ Total Roundwood Extracted (TQ=qx+ADC) in 1000 cum
ADC Apparent Domestic Roundwood Consumption (ADC = TQ-qx) in 1000 cum
NIW Roundwood that is charcoal and fuelwood (NIW=TQ-ILW) in 1000 cum
vqx Forest Product Export Revenue In million $US
Y Real Gross National Income In million $US
FS Financial Distress (Index)
A Total Foreign Reserves in million $US
M Aggregate Import Demand In million $US
GrY Growth Rate of Gross National Income

Concerning financial distress (FS) forest area industrially cleared was negatively and significantly (α= .025) affected by Ghanaian financial distress. This was consistent across wood extractive activities (Ω_i). Needless to say, this was surprising. The sign can only be explained by the local domestic origin of forestry operations. Because Ghana suffered through a protracted period of economic decline in the seventies and early eighties, access to foreign capital to finance forestry investment was limited. Consequently mean industrially cleared forest areas decreased. This coupled with the log export ban in 1979 could only have benefitted Ghanaian forest stock.

Both forest product export revenue (vqx) and foreign assets (A) significantly (α= .10) affect the forest area industrially cleared. Increased revenue from forest product exports tends to decrease forest clearing. Tentatively it seems that the timber trade does not adversely affect the forest environment. However, since the equation has qx in two places, it qualifies as a complex variable. Therefore caution is advised before drawing premature conclusions. Like forest product exports, increasing total foreign assets result in a decrease in industrially cleared forest areas. This is consistent with the findings of Capistrano and Kiker (1995).

Individually income is not significant; however, as noted previously, increasing income combined with increasing financial distress could potentially reduce logging pressure on Ghanaian forest stock. Aggregate import demand is likewise insignificant in the model.

Most of the results presented are representative of partial elasticity effects on Ghanaian forest stock and not marginal effects Unlike the growth rate in income the total effects of other variables on the forest area industrially cleared cannot be elicited without further analysis This is done in a later section

Wood Extraction

Parameter estimates for the wood extraction equations are shown in Table 8 2 Gross national income (Y) and the dummy variable for the 1983 economic reform program (ERP) demonstrate significant (α= 025) influences on the three categories of wood extraction The logarithm of gross national income appears to be strongly convex Therefore below a certain level of income reductions in gross national income cause rapid increases in wood extraction

The data suggest that the Ghanaian governments objective of revitalizing the forest sector as espoused in the mandate of the 1983 ERP has had a significant (α= 025) and positive effect on all forms of wood extraction The ERP s effect is slightly larger for aggregate roundwood extraction (TQ) when compared to apparent domestic consumption (ADC) of industrial roundwood and wood extracted for domestic use in the form of fuelwood and charcoal (NIW) (both estimates are 0 31)

The effect of financial distress on wood extraction defies a priori expectations Although significant (α= 10) it carries a negative sign indicating that as the country becomes more financially distressed the propensity to fell trees falls

Table # 2-- 3sls Parameter Estimates (with Standard Errors) for Ghanaian Wood Extraction, 1967-1994

Model with Q_i	=ln(TQ)	=ln(ADC)	=ln(NIW)
Dependent Variable	ln(TQ)	ln(ADC)	ln(NIW)
Intercept	268.42*** (58.69)	272.35*** (65.38)	272.47*** (68.88)
ln(Y)	-61.86** (14.12)	-62.86*** (15.46)	-62.94*** (16.28)
ln(Y)*FS	-0.01* (0.006)	-0.01* (0.006)	-0.008 (0.006)
$ln(Y)*FS^2$	0.002 (0.003)	0.003 (0.003)	0.002 (0.003)
$(ln(Y))^2$	3.76*** (0.83)	3.76*** (0.91)	3.77*** (0.97)
ln(vqx)	-0.38* (0.23)	-0.34 (0.25)	-0.36* (0.26)
$(ln(vqx))^2$	0.04 (0.03)	0.03 (0.03)	0.03 (0.03)
ln(A)	-0.01 (0.05)	0.01 (0.05)	0.02 (0.05)
ERP	0.33*** (0.09)	0.31*** (0.10)	0.31*** (0.10)

*significant at α= 10 **significant at α= 05 ***significant at α= 025

Q_i Roundwood Classification (i=TQ ADC NIW)
qx Volume Roundwood Exported in 1000 cum
ILW Industrially Extracted Roundwood in 1000 cum
TQ Total Roundwood Extracted (TQ=qx+ADC) in 1000 cum
ADC Apparent Domestic Roundwood Consumption (ADC = TQ-qx) in 1000 cum
NIW Roundwood (that is charcoal and fuelwood (NIW=TQ-ILW) in 1000 cum
vqx Forest Product Export Revenue in million $US
Y Real Gross National Income in million $US
FS Financial Distress (Index)
A Total Foreign Reserves in million $US
ERP 1983 Economic Recovery Program

The logic of the previous discussions related to financial distress and cleared forest area rationalizes the negative sign

It should be noted that financial distress does not affect wood extraction for charcoal and fuelwood (NIW) This too is surprising since one would expect the use of lower quality energy sources to increase as access to oil grew more limited

Forest product exports significantly (α= 10) affect aggregate wood extraction (TQ) and wood extraction for fuelwood and charcoal (NIW) but does not affect apparent domestic consumption of wood (ADC) This result is consistent with the assumption that industrial logging for the forest products trade opens the forest to other uses such as fuelwood and charcoal extraction for domestic uses

Forest Product Export Supply

Parameter estimates for forest product export supply are presented in Table 8 3. All estimated price parameters are positive and statistically different from zero (α= 025) Additionally the data suggests that Ghana's forest product export supply is highly price elastic, for a 1% increase in price Ghanaian export supply is expected to increase by a magnitude of at least 3 6

The real exchange rate (RXR) measured as cedi/$US is also highly significant (α= 025) The parameter demonstrates that depreciation of the cedi increases forest product export supply This implicitly reduces forest cover or the forest area industrially logged The real exchange rate on FAIL will be confirmed in the section on marginal effects

Table 6 3– 3sls Parameter Estimates (with Standard Errors) for Ghanaian Forest Products Export Supply 1967-1994

Model with Q	=ln(TQ)	=ln(ADC)	=ln(NIW)
Dependent Variable	ln(vqx)	ln(vqx)	ln(vqx)
Intercept	2 58 (4 66)	-3 05 (4 92)	-3 14 (4 81)
ln(RFPI)	3 72*** (0 77)	3 66*** (0 78)	3 68*** (0 77)
ln(W)	0 31 (0 60)	0 37 (0 60)	0 38 (0 66)
RXR	0 07*** (0 01)	0 07*** (0 01)	0 07*** (0 01)
GFR	-0 74*** (0.27)	-0 77*** (0.28)	-0 78*** (0 28)

***significant at α= 025

Q_i Roundwood Classification (i=TQ ADC NIW)
qx Volume Roundwood Exported in 1000 cum
vqx Forest Product Export Revenue in million $US
ILW Industrially Extracted Roundwood in 1000 cum
TQ Total Roundwood Extracted (TQ=qx+ADC) in 1000 cum
ADC Apparent Domestic Roundwood Consumption (ADC = TQ–qx) in 1000 cum
NIW Roundwood that is charcoal and fuelwood (NIW=TQ–ILW) in 1000 cum
RFPI Ratio of Ghana Forest Products Price to OECD Price (Unit Value 1987=100)
W OECD Real Gross Domestic Income (1987 = 100) in billion $US
RXR Real Ghana to US Exchange Rate (scaled by a factor of 10)
GFR 1979 log export ban

In 1979 the Ghanaian government imposed a log export ban in response to the felt need to promote forest industrialization for greater rent capture and to respond to global pressures to reduce destruction of primary forest via commercial logging The parameter estimate on the dummy variable for forest product restriction captures these policy effects The variable is highly significant (α= 025)

and negative. Therefore the ban effectively reduced Ghanaian forest product exports which could potentially increase Ghanaian forest cover.

The OECD real income term is not significant. This is not surprising since Ghana is not a major player in the world timber market.

Foreign Asset (Reserve) Availability

Table 8.4 presents the parameter estimates for the foreign asset equation. The sign on all parameters are consistent with expectations. All variables are highly significant ($\alpha = .025$) with the exception of new foreign loan disbursements (ND) which is relatively weakly significant ($\alpha = .10$). The real exchange rate and aggregate import demand (M) reduce reserve levels while gross national income and greater access to foreign loans increase reserve levels. Parameter estimates across all three equations are similar and demonstrate no significant deviations.

Marginal Effects

To comprehend the effects of individual variable's influence on the forest area industrially cleared it is imperative that marginal effects are calculated within the context of the simultaneous equation model. A common covariance matrix is used to jointly evaluate all marginal effects. The procedure used is to linearize the functions around the estimated parameter values and then employ standard

Table 8.4– 3sls Parameter Estimates (with Standard Errors) for Ghanaian Foreign Asset Availability 1967-1994

Model with Q,	=ln(TQ)	=ln(ADC)	=ln(NIW)
Dependent Variable	ln(A)	ln(A)	ln(A)
Intercept	19.41*** (6.81)	18.07*** (6.78)	-18.12*** (6.80)
RXR	-0.03*** (0.01)	-0.03*** (0.01)	-0.03*** (0.01)
ln(M)	1.12*** (0.30)	1.11*** (0.30)	1.19*** (0.30)
ln(Y)	3.80*** (0.58)	3.74*** (0.58)	3.74*** (0.58)
ln(ND)	0.22* (0.13)	0.23* (0.12)	0.23* (0.13)

*s gnificant at α= 10 **significant at α= 05 ***significant at α= 025

A Total Foreign Reserves in million $US
Q Roundwood Classification (i=TQ ADC NIW)
qx Volume Roundwood Exported in 1000 cum
ILW Industrially Extracted Roundwood in 1000 cum
TQ Total Roundwood Extracted (TQ=qx+ADC) In 1000 cum
ADC Apparent Domestic Roundwood Consumption (ADC = TQ-qx) in 1000 cum
NIW Roundwood that is charcoal and fuelwood (NIW=TQ-ILW) in 1000 cum
RXR Real Ghana to US Exchange Rate
M Aggregate Import Demand in million $US
Y Gross National Income in million $US
ND New Foreign Debt Disbursement, in million $US

formulas for the variance and covariance of linear functions of random variables [4]

Marginal influences on Ghanaian Forest Clearing from industrial logging are presented in Table 8.5. All variable's marginal influence on FAIL is significant with the exception of gross national income and new foreign debt issuances. Variables which tend to reduce marginal influences on depletion of Ghanaian forests include financial distress, the 1979 log export ban (GFR) and higher levels of foreign reserves (assets). Although new debt issuances is insignificant, it carries the correct sign. Since increased access to foreign loans contributes to Ghanaian foreign asset liquidity, the effect on industrial forest area is to reduce the rate of clearing.

Variables which exhibit depleting marginal influences on Ghanaian forests include forest product exports, the 1983 economic recovery program (ERP), relative forest product export price, growth of gross national income, all definitions of wood extraction, aggregate import demand and the real exchange rate. Although gross national income exhibits an insignificant marginal influence, its sign is correct.

Because the variables are measured in different units it is not appropriate to compare marginal influences across variables. However, it is feasible to compare the magnitudes of marginal influences across regressions. All estimates of marginal influences are relatively similar across regressions. The most obvious exceptions are the relative export price effect, ERP, GFR and the real exchange

[4]See Gallant and Jorgenson (1979) and Gallant and Holly (1980) for further details.

Table 6 5– Estimates of Marginal Influences (with Standard Errors) on Ghanaian Forest Area Industrially Logged 1967-1994

Model with Q	=ln(TQ)	=ln(ADC)	=ln(NIW)
Derivative w r t	change in HA	change in HA	change in HA
Gross National Income	0 083 (0 07)	0 01 (0 07)	0 02 (0 07)
Forest Product Exports	1 46*** (0.52)	1 38*** (0 54)	1 46*** (0.54)
Financial Distress	142.92*** (52 15)	150 38*** (57 61)	146.13*** (56 19)
ERP	207 56** (105 51)	208 70** (108 53)	197 06** (107 34)
GFR	107 56** (54 74)	104 88** (56 37)	107 18** (55 62)
Relative Price	535.35*** (284 31)	587 92*** (293 48)	539 57*** (284 17)
Foreign Assets	-0 36* (0.25)	-0 43* (0.27)	-0 38* (0.26)
Growth Rate of Gross National Income	5 34*** (2 91)	6 84*** (2 98)	5 88*** (3 07)
Wood Extraction- TQ	0 05** (0 03)		
Wood Extraction- ADC		0 06** (0 03)	
Wood Extraction- NIW			0 06* (0 03)
Aggregate Imports	0.24*** (0 10)	0.23** (0 11)	0.23*** (0 10)
New Debt	-0 14 (0 11)	-0 19 (0 13)	-0 14 (0 12)
Real Exchange Rate	11 47** (3 88)	10 52*** (4 02)	10.36*** (4 02)

*significant at α= 10
**significant at α= 05
***significant at α= 025

Table 8.5--continued

HA Forest area Industrially logged IN 1000 hectares
Q Roundwood Classification (I=TQ ADC NW)
qx Volume Roundwood Exported in 1000 cum
ILW Industrially Extracted Roundwood, in 1000 cum
TQ Total Roundwood Extracted (TQ=qx+ADC) in 1000 cum
ADC Apparent Domestic Roundwood Consumption (ADC = TQ-qx) in 1000 cum
NW Roundwood that is charcoal and fuelwood (NW=TQ ILW) in 1000 cum
ERP Economic Reform Program of 1983
GFR Log Export Ban of 1979

rate. The relative export price is relatively larger for the regression estimated with total wood removal (TQ) as an indicator of wood extraction when compared with regressions employing wood for apparent domestic consumption (ADC) and wood removed for charcoal and fuelwood consumption (NIW) as indicators of wood extraction. The economic recovery program (ERP) seems to have a smaller depleting effect in regressions employing NIW as the indicator of wood extraction. This effect can be explained as a manifestation of multiple domestic sources of firewood and charcoal outside of industrial forest areas. Therefore when the 1979 log export ban (GFR) was implemented, regressions with NIW demonstrate greater conserving influences than regressions with ADC. The difference lies in the lack of domestic substitutes for industrial roundwood. Industrial roundwood for domestic consumption had to be obtained from industrial forest areas. The real exchange rate has relatively greater depleting influence in regressions employing aggregate wood extraction (TQ) than regressions employing domestically defined wood extraction (ADC and NIW). Since the real exchange rate influences the relative prices perceived by the Ghanaian logging industry, the international market has a significant influence on Ghanaian forest areas via the real exchange rate effect. Capistrano and Kiker (1995) found similar influences in their global cross sectional study.

Although all within regression marginal influences cannot be compared in Table 8.5, it is possible to compare subsets of variables with similar measurement. Thus gross national income, forest product export supply (million US$ value gained

in revenue is used as a proxy) total foreign assets aggregate import demand and new foreign debt issuances all measured in million $US are comparable. Within this subset of variables forest product export supply exhibits the greatest marginal effect on industrially logged forest area in absolute terms followed by total foreign assets aggregate import demand new debt issuances and gross national income. Forest product export supply has a depleting effect on Ghanaian forest stock. Since the dependent variable is measured in 1000 hectares a million $US increase in forest product export revenue results in at most 1 460 hectares of lost Ghanaian forest stock. On the other hand total foreign assets reduce pressure on Ghanaian forest stock at the margin. A million $US dollar increase in Ghanaian foreign reserves translates into at least 380 hectares of Ghanaian forest stock not logged. Like forest product exports aggregate import demand exhibits depleting marginal influences on Ghanaian forest stock. A million $US dollar increase in aggregate import demand results in at most 240 hectares of lost Ghanaian forest stock. Since gross national income and new debt issuances are insignificant, their marginal influences will not be discussed.

The real exchange rate and the growth rate of gross national income can be compared by virture of them being rates. Both variables demonstrate depleting marginal influences on Ghanaian forest stock. A unit increase in the growth rate of Ghanaian gross national income results in at most 9 880 hectares of lost Ghanaian forest stock while a unit increase in the cedi/US real exchange rate translates into at most 1 147 hectares of lost Ghanaian forest stock. Clearly policy

objectives aimed at boosting Ghanaian gross national income and stabilizing the bi-lateral exchange rate come at the expense of primary forest resources

Elasticities

To facilitate comparison across all variables FAIL elasticities are calculated Table 8 6 present these calculations with standard errors The signs are similar to those of Table 8 5 therefore this section is void of such discussion Instead the focus is on the differences in elasticities calculated at data means

The table underscores the general inelastic effect of all variables on Ghanaian forest area industrially logged Comparing estimates across regressions it is clear that the elasticities are quite similar Only in the cases of relative forest product prices wood extraction and the real exchange rate are there marked differences in elasticity estimates Even then the differences are not strikingly large Relative forest product price is inelastic across all regressions however regressions estimated with wood extraction defined in the aggregate (TQ) seems more elastic The same holds for elasticity estimates regarding the real exchange rate Wood extraction defined as apparent domestic consumption seems to have a relatively greater influence on industrially logged forest area when compared with other definitions (TQ and NIW)

Ranking statistically significant elasticity estimates the forest area industrially logged is most responsive to the various definitions of wood extraction These are followed by relative forest product price aggregate import demand the

Table 5 6– Estimates of Ghanaian FAIL Elasticities Evaluated at Data Means (with Standard Errors) 1967 1994

Model with Q	=ln(TQ)	=ln(ADC)	=ln(NIW)
Derivative w r t	% change in HA	% change in HA	% change in HA
Gross National Income	0 02 (0 38)	0 08 (0 42)	0 14 (0 44)
Forest Product Exports	0 16*** (0 06)	0 17*** (0 07)	0 17*** (0 07)
Financial Distress	-0 01*** (0 003)	-0 01*** (0 003)	-0 01*** (0 003)
ERP	0 25** (0 13)	0 26** (0 13)	0 24** (0 13)
GFR	-0 13** (0 07)	-0 13** (0 07)	-0 13** (0 07)
Relative Price	0 60*** (0 28)	0 61*** (0 27)	0 62*** (0 27)
Foreign Assets	-0 15* (0 08)	-0 16* (0 18)	-0 14* (0 18)
Growth Rate of Gross National Income	0 02*** (0 01)	0 02*** (0 01)	0 02*** (0 01)
Wood Extraction- TQ	0 78** (0 41)		
Wood Extraction- ADC		0 84** (0 45)	
Wood Extraction- NIW			0 78* (0 45)
Aggregate Imports	0 35* * (0 14)	0 32** (0 15)	0 33*** (0 15)
New Debt	0 03 (0 03)	-0 04 (0 03)	-0 03 (0 03)
Real Exchange Rate	1 78*** (0 62)	1 63*** (0 62)	1 60*** (0 62)

*significant at α= 10
**significant at α= 05
***significant at α= 025

Table 5.5--continued

HA Forest area Industrially logged IN 1000 hectares
Q Roundwood Classification (=TQ ADC NIW)
qx Volume Roundwood Exported in 1000 cum
ILW Industrially Extracted Roundwood in 1000 cum
TQ Total Roundwood Extracted (TQ=qx+ADC) in 1000 cum
ADC Apparent Domestic Roundwood Consumption (ADC = TQ-qx) in 1000 cum
NIW Roundwood that is charcoal and fuelwood (NIW=TQ-ILW), in 1000 cum
ERP Economic Reform Program of 1983
GFR Log Export Ban of 1979

1983 economic recovery program (ERP) forest product export supply the real cedi/US bi-lateral exchange rate total foreign assets the 1979 log export ban (GFR) the growth rate of gross national income and financial distress The rankings hold across all regressions

Taken as a group the top eight elasticity influences suggest that openness to international influences has effects on the Ghanaian forest area industrially logged It seems that the wood extraction combined with Ghana s responsiveness to forest product relative price increases reduce industrial forest stock Furthermore the location of aggregate import demand and the 1983 ERP in the (top five) elasticity estimates suggest that the Ghanaian government's objective of revitalizing the domestic economy through increased sectoral productivity and more liberalized trade lead to e reduction in total forest stock. However because the responsiveness of forest area industrially logged is inelastic, it takes large increases in these variables to have an appreciable effect. Total forest stock loss in Ghana is currently occurring at 2% per year which exceeds the African average This suggests that changes in exogenous variables have been large enough to appreciably reduce Ghana s total forest stock. Naturally forest product export supply and changes in the exchange rate environment contribute to this process

The 1979 log export ban policy reform has had a weak conserving influence on Ghanaian forest stock. Given the Ghanaian government's willingness to loosen log ban restrictions in the early years of the 1983 ERP this is not surprising The government was constrained by a weak economy high foreign debt and small

shrinking foreign reserve balances and a declining exchange rate. The decision to relax log export restrictions in such an environment was a logical choice.

Changes in the levels of financial distress and the growth rate of gross national income have no effect on Ghanaian forest area industrially logged. The negative sign on financial distress suggests financial distress reduces pressure on Ghanaian forest stock; however, an elasticity estimate of -0.01 is essentially zero. Likewise, an estimate of 0.02 indicates that the effect of changes in the growth rate of gross national income is essentially zero. As a consequence, the relatively large marginal influences suggested for financial distress and the growth rate of gross national income in Table 8.5 are misleading. Moreover, the elasticities demonstrate that the real exchange rate has substantively more effect on changes in Ghanaian forest stock than does the growth rate of gross national income. The somewhat misleading marginal estimates suggest otherwise.

The elasticities of Table 8.6 are calculated at data means. It is quite possible that the averages do not truly represent each data point; therefore, examining the elasticities at each data point may provide greater insight into the relationship between exogenous variables and the forest area industrially logged. The results of the data point evaluations are presented in Tables 8.7a – 8.7c, without standard errors. The three tables can be analyzed along three lines: 1) whether the time series elasticity estimates starkly differ from elasticities calculated at data means; 2) whether there are surprises; and 3) whether there are noticeable trends in elasticity estimates.

Comparison of Table 8 6 and Tables 8 7a – 8 7c reveals that the estimates are quite similar with a several exceptions Elasticities with demonstratable differences include those with respect to gross national income relative export price, all definitions of wood extraction and the real exchange rate It seems that data means do not fairly represent the elasticity of forest area industrially logged with respect to gross national income At the data mean the elasticity is essentially zero however at data points the elasticity is strictly positive and very elastic throughout the time series This suggests that Ghanaian forest policy is intimately related to the national income cycle Also while the elasticity with respect to relative forest product price does not vary as noticeably as that concerning gross national income it is clear that at data points the estimate is still inelastic but much closer to being elastic. This is important. This suggests that Ghana's industrial forest area logged is much more responsive to relative forest product prices than is suggested by mean data points The behavior of the elasticities with respect to the real exchange rate and all categories of wood extraction also suggest greater degrees of responsiveness at data points than at date means

Elasticity estimates at date points offer two obvious surprises one is with respect to gross national income already discussed. and ther other is with respect to financial distress when considering wood extraction defined as apparent domestic consumption (ADC in Table 8 7b). These estimates are positive for all but four years (1983 – 1986) and are dramatically different from Tables 8 7a and 8 7c, whose elasticity estimates are negative from 1983 to the end of the data set, 1994

Table 8 7a-- Estimates of Ghanaian FAIL Elasticities Evaluated at Data Points for Regressions with Wood Extraction Defined as Total Wood Removed (TQ), 1968 - 1994

YEAR	GNI	EXPORTS	FS	ERP	GFR	PRICE	ASSETS	GR-GNI	TQ	IMPORT	DEBT	EXCHRT*
1968	-2 439	0 123	0 042			0 459	0 149	0 046	0 827	0 351	-0 033	1 779
1969	8 404	0 140	0 076			0 522	-0 147	0 134	0 880	0 352	-0 033	1 936
1970	0 867	0 142	0 222			0 526	-0 146	0 002	0 844	0 352	-0 033	1 966
1971	-2 850	0 133	0 118			0 499	0 146	-0 057	0 822	0 351	0 033	1 777
1972	1 728	0 156	0 297			0 581	-0 147	-0 038	0 871	0 352	0 033	2 506
1973	14 688	0 233	0 322			0 865	-0 148	0 215	1 021	0 354	-0 033	3 052
1974	5 090	0 199	0 301			0 730	-0 147	0 087	0 937	0 353	0 033	2 584
1975	7 328	0 161	0 171			0 674	-0 147	-0 124	0 858	0 352	-0 033	2 018
1976	-6 175	0 183	0 185			0 681	-0 147	-0 107	0 878	0 352	-0 033	1 384
1977	8 228	0 192	0 302			0 676	-0 147	0 131	0 967	0 352	-0 033	0 565
1978	5 520	0 154	0 196			0 612	-0 148	0 575	0 838	0 352	-0 033	0 579
1979	-0 455	0 140	0 127		-0 104	0 516	-0 145	-0 016	0 745	0 351	-0 033	0 565
1980	3 494	0 132	0 083		0 098	0 491	-0 145	0 042	0 715	0 350	-0 033	0 408
1981	-3 133	0 113	0 134		0 054	0 421	-0 144	-0 060	0 586	0 349	-0 032	0 178
1982	6 920	0 116	0 072		0 088	0 443	-0 143	-0 165	0 494	0 347	-0 032	0 155
1983	2 170	0 142	-0 144	0 161	0 106	0 528	-0 143	0 022	0 499	0 348	-0 032	0 266
1984	6 619	0 145	-0 100	0 173	0 108	0 541	-0 143	0 095	0 533	0 348	-0 032	0 612
1985	4 039	0 153	-0 088	0 195	-0 114	0 569	-0 144	0 051	0 589	0 349	-0 032	1 159
1986	4 381	0 183	-0 076	0 217	-0 121	0 608	-0 145	0 058	0 686	0 350	-0 032	1 581
1987	2 514	0 169	-0 123	0 264	-0 146	0 741	-0 145	0 027	0 911	0 351	-0 033	2 408
1988	4 581	0 204	-0 163	0 267	-0 152	0 758	-0 146	0 061	0 920	0 351	-0 033	2 566
1989	2 153	0 180	-0 161	0 248	-0 141	0 707	0 146	0 022	0 785	0 351	0 033	2 884
1990	2 447	0 214	-0 169	0 267	-0 156	0 769	-0 146	0 026	0 922	0 351	-0 033	2 744
1991	4 901	0 183	0 125	0 264	0 136	0 682	-0 146	0 064	0 810	0 351	-0 033	2 271
1992	2 301	0 253	-0 161	0 281	-0 185	0 841	-0 147	0 024	0 964	0 352	-0 033	3 333
1993	2 589	0 284	-0 132	0 280	-0 212	1 059	0 147	0 030	0 956	0 352	0 033	4 491
1994	4 798	0 336	-0 110	0 303	-0 251	1 258	-0 147	0 063	0 832	0 353	-0 033	6 324

* The real exchange rate data is deflated by a factor of 10

Table 8.7b– Estimates of Ghanaian FAIL Elasticities Evaluated at Data Points for Regressions with Wood Extraction Defined as Apparent Domestic Consumption (ADC) 1968 1994

YEAR	GNI	EXPORTS	ES	ERP	GFR	PRICE	ASSETS	GR-GNI	ADC	IMPORT	DEBT	EXCHRT*
1968	2 525	0 112	0 012			0 408	-0 161	0 052	0 885	0 324	-0 037	1 559
1969	6 735	0 125	0 023			0 456	-0 161	0 141	0 921	0 324	-0 037	1 675
1970	0 318	0 128	0,082			0 473	0 161	0 002	0 903	0 324	-0 037	1 736
1971	3 054	0 123	0 042			0 451	-0 161	-0,060	0 879	0 325	0 037	1 590
1972	1 786	0 141	0 132			0 514	0 161	-0 040	0 933	0 324	0 037	2 188
1973	15 183	0 189	0 127			0 723	-0 158	0,226	1 063	0 322	-0 037	2 624
1974	5 268	0 173	0 125			0 634	0 160	0 071	1 003	0 323	-0 037	2 218
1975	7 587	0 183	0 061			0 595	0 160	-0 131	0 961	0 323	-0,037	1 787
1976	-6 392	0 169	0 070			0 616	-0 160	-0 112	0 940	0 324	-0 037	1 220
1977	9 551	0 159	0 135			0 617	0 161	0 138	0 928	0 324	-0 037	0 589
1978	5 626	0 159	0 076			0 569	-0 161	0 079	0 888	0 324	-0 037	0 531
1979	-0 471	0 140	0 051		-0 108	0 511	-0 162	-0 019	0 787	0 326	-0 039	0 548
1980	3 617	0 135	0 036		-0 104	0 494	-0 163	0 045	0 765	0 325	-0 038	0 404
1981	-3,243	0 129	0 069		-0 069	0 472	-0 164	0 063	0 806	0 328	0 038	0 199
1982	10 278	0 142	0 038		-0 108	0 513	-0 166	0 173	0 487	0 330	-0 038	0 180
1983	2 240	0 165	-0 008	0 163	-0 127	0,602	-0 165	0 023	0 531	0 329	0 038	0 300
1984	7 182	0 166	-0 027	0 175	-0 128	0 607	-0 165	0 100	0 570	0 329	-0 038	0 602
1985	4 161	0 166	-0 021	0 186	-0 130	0 617	-0 164	0 054	0 641	0 328	-0 038	1 245
1986	4 536	0 174	-0 016	0 216	-0 134	0 636	-0 163	0 058	0 713	0 327	-0 036	1 635
1987	2 803	0 185	0 007	0 266	-0 150	0 713	-0 161	0 035	0 868	0 325	-0 037	2 295
1988	5 032	0 186	0 060	0 269	-0 153	0 727	-0 161	0 067	0 876	0 325	-0,037	2 437
1989	2 229	0 181	0 051	0 251	-0 147	0 699	-0 162	0 023	0 818	0 325	-0 038	2 829
1990	2 534	0 210	0 069	0 269	-0 162	0 766	-0 161	0 029	0 880	0 325	-0 037	2 617
1991	5 074	0 179	0 007	0 268	-0 137	0 652	-0 161	0 060	0 867	0 325	-0 037	2 147
1992	2 363	0 245	0 054	0 283	-0 189	0 897	-0 161	0 025	0 925	0 324	-0 037	3 153
1993	2 794	0 280	0 015	0 282	-0 218	1 023	-0 161	0 032	0 920	0 324	-0 037	4 315
1994	4 987	0 325	0 008	0 306	-0 251	1 190	-0 160	0,066	0 998	0 323	-0 037	8 960

* The real exchange rate data is deflated by a factor of 10

Table 8 7c-- Estimates of Ghana an FAIL Elasticities Evaluated at Data Points for Regressions with Wood Extraction Defined as Firewood and Charcoal (NIW) 1968 - 1994

YEAR	GNI	EXPORTS	FS	FRP	GFR	PRICE	ASSETS	GR-GNI	NIW	IMPORT	DEBT	EXCHRT*
1969	2 545	0 134	0 044			0 492	-0 142	-0 052	0 829	0 332	-0 033	1 778
1969	6 813	0 147	0 078			0 538	0 141	0 141	0 860	0 331	0 033	1 972
1970	0 926	0 150	0 238			0 553	0 141	0 002	0 843	0 331	0 033	1 931
1971	3 079	0 145	0 123			0 532	0 142	-0 060	0 821	0 332	-0 033	1 782
1972	1 803	0 191	0 317			0 581	0 141	-0 040	0 871	0 331	0 033	2 403
1973	15 304	0 214	0 339			0 789	0 138	0 227	1 021	0 328	-0 032	2 654
1974	5 311	0 191	0 319			0 704	0 140	0 071	0 937	0 330	-0 033	2 367
1975	7 848	0 182	0 179			0 670	0 140	-0 132	0 858	0 330	-0 033	1 901
1976	-6 443	0 187	0 185			0 687	-0 141	0 113	0 877	0 331	-0 033	1 308
1977	9 628	0 187	0 323			0 688	-0 141	0 138	0 888	0 331	-0 033	0 942
1978	5 873	0 175	0 205			0 643	-0 142	0 080	0 829	0 332	-0 033	0 575
1979	-0 475	0 160	0 135		-0 124	0 588	-0 143	0 020	0 745	0 333	0 033	0 804
1980	3 648	0 156	0 098		-0 121	0 573	-0 144	0 045	0 715	0 334	-0 034	0 448
1981	-3 259	0 151	0 140		-0 117	0 556	-0 148	-0 063	0 565	0 337	-0 034	0 221
1982	10 360	0 184	0 079		-0 127	0 804	-0 149	0 174	0 484	0 339	-0 035	0 200
1983	2 264	0 185	-0 132	0 154	-0 144	0 861	-0 143	0 023	0 498	0 338	0 034	0 327
1984	7 220	0 196	-0 100	0 165	-0 144	0 884	-0 147	0 161	0 533	0 337	-0 034	0 980
1985	4 214	0 196	-0 089	0 185	-0 149	0 961	-0 149	0 054	0 599	0 336	-0 034	1 345
1986	4 572	0 192	-0 077	0 206	-0 149	0 707	-0 145	0 059	0 665	0 335	-0 034	1 755
1987	2 624	0 212	-0 117	0 251	-0 184	0 778	-0 142	0 029	0 910	0 332	-0 033	2 421
1984	5 673	0 215	-0 144	0 254	-0 197	0 792	0 142	0 067	0 820	0 332	-0 033	2 563
1989	2 248	0 209	-0 143	0 237	-0 162	0 766	-0 143	0 023	0 764	0 333	-0 033	2 781
1990	2 554	0 225	-0 145	0 254	0 175	0 830	-0 142	0 028	0 821	0 332	-0 033	2 738
1991	5 115	0 198	-0 120	0 251	0 152	0 721	-0 142	0 068	0 810	0 332	-0 033	2 287
1992	2 402	0 258	0 144	0 268	0 201	0 951	-0 141	0 025	0 964	0 331	-0 033	3 243
1993	2 816	0 291	0 125	0 268	0 228	1 069	0 141	0 032	0 858	0 331	-0 033	4 388
1994	5 007	0 333	-0 105	0 289	-0 258	1 228	-0 140	0 068	0 932	0 330	-0 033	5 887

* The real exchange rate data is deflated by a factor of 10

Tables 8.7a - 8.7c—continued

GNI gross national income
Exports exports of forest products
FS financial distress
ERP dummy variable for the 1983 economic recovery program
GFR dummy variable for the 1979 log export ban
Price relative forest product export price
Assets total stock of foreign reserves
Gr-GNI growth rate of gross national income
TQ total roundwood extracted (in 1000 cubic meters)
ADC wood extraction defined as apparent domestic consumption
NIW wood extraction defined as firewood and charcoal
Import aggregate import demand
Debt new foreign debt issuances
EXCHRT the real exchange rate (cedi/$US)

Although the estimate remains very small the deviation signals that this category of wood extraction affects Ghanaian forest area differently from the other two categories Financial distress when considering ADC seems to have a slight forest depleting effect which was postulated at the start of the study This is in contrast to the forest conserving effects of financial distress when considering NIW and TQ

Elasticities calculated at data points show increasing trends over the last eight years (1987 - 1994) Excluding elasticities with respect to foreign debt aggregate import demand growth in gross national income and financial distress calculated elasticities demonstrate a propensity to get less inelastic and approach one and in some cases exceed one (i e the case of relative forest product price) This evidence suggests once more that increased forest utilization is an important and growing component of revitalizing the Ghanaian economy A close look at the elasticity with respect to ERP supports the conclusion

Summary

A multiple equation simultaneous system is estimated over the 1967 - 1994 period to assess economic influences on the Ghanaian forest area industrially logged (FAIL) Model results affirm that the international trade in forest products catalyzes the industrial forest clearing process in Ghanaian Furthermore Ghana's forest product export supply is extremely price elastic (on the order of 3) Policy reform appears to have significant influences on Ghanaian forest stock. Restrictions on log exports via the 1979 log export ban slows logging under all

model scenarios. However the economic reform program initiated four years after the log export ban clearly increased industrially cleared forest area. Therefore assuming a depleting effect on Ghanaian forest area. The ERP's effect on forest clearing is evident across all categories of wood extraction (Table 5.5). Additionally, roundwood extraction (Q_1) proves to be significant in all models. Combining both results suggests that the Ghanaian government's objective of revitalizing the forestry sector comes at the expense of depleted forest cover.

The need for foreign assets and the burdens of foreign debt demonstrated that the financial environment has differential effects on Ghanaian forest stock. Foreign revenue earned via the trade in forest products increases forest depletion in all models. However, increasing foreign reserves mitigates forest depletion under all cases. When the burden of foreign debt is considered all models indicate that Ghana is less likely to deplete forest cover under increasing financial distress from foreign debt. The first two effects are not surprising, however the third, financial distress, suggests that foreign debt, specifically stress from foreign debt, is not a problem for Ghanaian forest stock, in fact foreign debt and financial distress may work to slow forest use. This result was not postulated a priori. This could imply that greater access to international capital is possibly a means of slowing Ghanaian forest depletion. Such a deduction partially bolsters the significance of increased foreign reserves in reducing forest depletion. Such a conclusion must be taken with care since parameter estimates on financial distress are quite small

Marginal analysis at data means reveals that long term economic objectives as measured by the growth rate of gross national income (GrY) is consistent with a priori expectations However short-term economic objectives as measured by gross national income is statistically zero Increases in GrY have negative impacts on forest stock. The use of forest resources and any primary resource to improve long term national economic welfare is consistent with rational economic behavior However we worry when primary resources are used to meet current economic needs without consideration for the future That is if the Ghanaian government is using forest stock to satisfy present day consumption without investing in reforestation then the positive signs are bothersome All indications are that reforestation is a low priority in Ghana

Other variables than the growth rate of gross national income exhibit significant marginal influences on the Ghanaian forest area industrially logged These include the relative forest product price forest product export supply the real exchange rate the two policy dummy variables (the 1983 economic recovery program and the 1979 log export ban) all definitions of wood extraction aggregate import demand total foreign assets and financial distress Financial distress the 1979 log export ban and total foreign assets demonstrate marginal influences that ease logging pressure on Ghanaian forest stock while all other listed variables exert depleting marginal influences on Ghanaian forest stock. The magnitudes of marginal influences cannot be compared since all variables are not standardized

Noteworthy among variables that do not marginally influence Ghanaian industrial forest clearing is new debt issuances. Since new foreign loans represent a form of foreign capital financing it was postulated that this variable would exert conserving marginal influences on Ghanaian forest stock. Indeed the result is surprising.

To facilitate comparison of exogenous variable influences on FAIL, elasticities evaluated at data means and data points are calculated. Elasticities at data means maintain signs observed for marginal influences and are collectively inelastic. Therefore a ten percent increase in any exogenous variable changes FAIL by less than ten percent. Essentially it takes large changes in any of the models exogenous variables to have appreciable effects on Ghanaian forest stock. Among this set of calculation, the most influential variables in decreasing order of influence are: wood extraction, relative forest product price, aggregate import demand, the 1983 economic reform program, forest product export supply, the real exchange rate, total foreign assets, and the 1979 log export ban.

The effects of changes in the growth rate of gross national income and financial distress are also statistically significant, however, their influences are for all purposes negligible. Also, the contributions of gross national income and new foreign debt issuances are negligible and statistically zero.

Elasticities at data points are calculated and presented without standard errors. The analysis reveals that elasticity estimates evaluated at data means differ from estimates evaluated at data points for gross national income throughout the

data set, and relative forest product price plus other variables at later stages of the data set. While gross national income demonstrates zero effect at data means it demonstrates mostly positive and elastic estimates at all but two data points. This revelation is very important. It is consistent with the literature and it indicates that national income objectives are tied to primary resource use. If data means do not adequately represent the distribution of data points, then it is possible that gross national income's influence could have been mis-judged when evaluated at the mean.

Relative forest product price, wood extraction, forest product export supply, the real exchange rate and the two policy variables also show differences at data means and data points, however these differences are not drastic. The differences are more related to changes over time: the estimates become less inelastic (in the cases of wood extraction, forest product export supply, the real exchange rate and the two policy variables) and more elastic (in the case of relative forest product price) in the latter stages of the data set.

Some elasticities are similar to elasticities calculated at data means and remain constant throughout the data set. These include new foreign debt issuances, aggregate import demand growth rate of gross national income and total foreign assets.

Financial distress elasticities evaluated at data points are different from elasticities evaluated at data means. Data point elasticities tend to be positive and inelastic (forest stock depleting response) up to 1982, and become negative and

inelastic (forest stock conserving response) from 1983 - 1994. This pattern is identical for two regressions, however, for the third regression financial distress elasticity is positive and inelastic (forest stock depleting response) throughout the data set except for the 1983 - 1986 interval where it is negative and elastic. These results imply that increased external financing (foreign capital flows) into Ghana after the implementation of the 1983 economic reform program reduced financial distress and slightly eased pressure on Ghanaian forest stock after 1983.

In the case of regressions estimated with a definition of wood extraction as apparent domestic consumption (ADC), FAIL has a depleting response to increases in financial distress. It is conceivable that increasing financial distress causes Ghana to increase its domestic use of primary resources since import capacity is limited in financially constrained times. It should be noted that of the three regressions, financial distress elasticity estimates are appreciably smaller and closer to zero for the ADC regression. Therefore, financial distress influence is practically zero (i.e. no response of FAIL to total domestic wood use).

CHAPTER 9
CONCLUSIONS AND FUTURE DIRECTION

Conclusions

Motivated by the assumption that the international forest product trade catalyzes the deforestation process in tropical countries this study presents a partial economic analysis of the influences on tropical deforestation It focusses attention on the forest area industrially logged Primarily it considers influences such as forest product trade foreign asset availability and distress from foreign debt on the forest area industrially logged (FAIL)

Since logging often constitutes the first step towards deforestation the area of closed broadleaved forests industrially logged is used as the indicator of tropical forest depletion This measure reflects in part government's forest allocation decisions and influence on human behavior

Theoretical analysis using an optimal control model conditionally implicates wood extraction aggregate import demand national income objectives in the short-term and long-term forest product export supply and profits from the forest product trade as depletive influences on tropical forest stock These conditional influences depend in some part on the marginal propensity of tropical countries to obtain income by depleting tropical forests and the growth rate of the shadow value of

tropical moist forests Tropical countries exhibiting positive marginal propensities to obtain income via industrial logging and relatively high social discount rates in forest usage tend to deplete forest stocks due to rising income growth rates increasing need for foreign assets and the importance of maintaining credit-worthy status via timely repayment of foreign debt obligations

Empirical analysis using a simultaneous equation model and time series data spanning 1967 - 1994 and a case study of Ghana implicate national income all forms of wood extraction forest product export supply and related variables domestic economic policy and the growth rate in national income as having depletive influences on Ghanaian forest stock. Alternatively the empirical analysis identifies increasing financial distress from foreign debt, increases in foreign reserves and a national ban on raw industrial log exports as slowing use of Ghanaian forest stock

Theoretically increasing financial distress tends to deplete forest stock however the empirical case reveals a contradiction A scan of the data set on raw foreign debt disbursement and cleared forest area show that during the mid to late 1970s Ghana's flow of foreign loans fell dramatically while forest area cleared increased The situation reversed from 1983 to the end of the sample period the flow of international loans to Ghana increased dramatically while forest area cleared increased less relative to increases in the previous decade Additionally the rate of growth of gross national income mirrored the trend in international capital flows over the two periods One can only surmise then that there were

other things at work which influenced the inverse empirical relationship between Ghanaian financial distress and forest area industrially logged

The log export ban of 1979 and the economic recovery program (ERP) of 1983 are two significant policy changes which, respectively reduced forest stock depletion and attracted increased external capital flows into Ghana from the early 1980s to 1994 Thus successful domestic environmental policies and strong economic reforms along with increased international capital flows slowed use of Ghanaian tropical forest stock. The applicable lesson for the new policy process is obvious encourage tropical countries to implement strict domestic environmental policies along with feasible economic reform that attracts foreign direct investment and back this encouragement with accessible capital This was a serendipitous occurrence in the case of Ghana

The influence of domestic consumption on forest depletion in the theoretical model is consistent with empirical results The theoretical analysis shows that when consumption benefits outweigh the cost of forest transformation aggregate import demand will exert depleting pressures on Ghanaian forest stock Also as long as the marginal propensity to secure income from liquidating forest stocks is greater than zero gross national income will exert depletive pressures on Ghanaian forest stock. The empirical model confirms that increasing the growth rate of gross national income and increasing national demand for imported goods increase the potential for depleting Ghanaian forest stock. Therefore it is not the desire to finance national consumption of imported goods that influences the deforestation

process but the need for capital to promote macro-economic objectives The importance of foreign capital (money) input is implicit in the achievement of these objectives A convenient means of generating this capital is via the trade in forest products and the substitution of low energy sources (wood and charcoal) for imported oil

Elasticities evaluated at data means identify wood extraction as the most important variables which exert depleting pressures on Ghanaian forest stock For every 1000 cubic meters of industrial roundwood extracted 50 hectares of forest land is lost. The case is even more extreme for forest product exports which ranks as the fifth most influential variable on FAIL based on elasticity estimates evaluated at data means For every 1000 cubic meters of industrial roundwood exported 1 146 hectares of forest land is sacrificed Since wood extraction for the world export market is more discriminating (demanding the highest quality wood) than general wood extraction to satisfy domestic and export markets combined the previous results make sense The results imply that selective logging for the export market is relatively more environmentally costly because it results in relatively greater amounts of lost forest land

Other variables which rank very high on the elasticity list are (with rank in parenthesis) relative forest product price (2) aggregate import demand (3) the 1983 economic recovery program dummy variable (4) and the real exchange rate (6) Total foreign assets is a significant factor whose influence reduces pressure on Ghanaian forest It ranks seventh on the list however when one considers that

forest product export is a means of increasing total foreign reserves It's importance magnifies An increase of one million $US results in 390 000 hectares of conserved forest area if the foreign reserve source is not related to wood extraction activities If this million dollars originates from forestry related activities then forest area would be lost (depleted) rather than conserved

A central postulate of this study contends that increasing distress from foreign debt causes tropical developing countries to deplete forest stocks As stated previously empirical results imply the reverse Increasing financial distress from foreign debt reduces pressure on forest stock. This result is surprising until perusal of elasticities calculated at data means conveys that although the influence is significant It is essentially zero Thus, financial distress from foreign debt is not a statistically important factor in Ghanaian forest stock depletion Note, however that it is a real variable in the Ghanaian economy

The empirical and analytical results surrounding financial distress and foreign reserves underscore the importance of access to liquid funds such as international credit from international financial institutions such as the World Bank and the International Monetary Fund The evidence shows that although financial distress increased dramatically after 1982 economic reforms (structural adjustment reforms) since 1983 attracted increased flows of international loans grants and credit into Ghana These international dollars effectively dampened the depleting effects of increasing financial distress on forest stocks so much that the data shows

financial distress reducing pressure on Ghanaian forest stock up to 1994 (the end of the data set)

Of course money alone does not conserve Ghanaian forest stock. International financial institutions such as the World Bank seem to now realize that congruent financial policy and forest policy are the mechanisms which can reduce pressure on forests in tropical countries. As such their new policy agenda as it relates to conservation of tropical forests is to require practical and workable domestic forest policy reforms as a precondition of external financial assistance. This militates against excessive logging. The 1979 log export ban is one such policy which has the potential to exert conserving influences on Ghanaian forest stock. Combined increasing external financial capital flows domestic economic policy reforms and domestic forestry reforms can help conserve Ghanaian forests.

The economics of deforestation is a multifaceted problem of human behavior. Human behavior as it relates to production consumption trade international finance demography and fiscal policy permeates economic analysis of deforestation and shapes the policy environment. Consequently it must be understood that the deforestation problem is complex and demands the recognition that it is the confluence of human behaviors which drives the deforestation process. No single factor can be blamed for the loss of forest cover and its associated services.

In light of the completed analysis it pays to address some questions raised in chapter 3. First previous studies tend to implicate the movements of the shifting

cultivator population changes and population growth (mostly rural) as the primary factors associated with tropical deforestation. However this view can be erroneous since it implies that the tropical deforestation problem is one solely associated with the poor and landless. Certainly the poor are a part of the problem however they are not the whole story. This analysis which views deforestation as a multi stage process starting with industrial logging shows that other factors facilitate access into forests and therefore are indirect influences on tropical forest depletion. In the case of Ghana domestic economic policy foreign exchange requirements exchange rate fluctuations, and pressures to minimize the cost of accessing foreign funds by maintaining creditworthiness all impact on the decision to give concessions to industrially log forest areas. Once the first stage of industrial logging is complete the forest now is open to secondary users i.e. shifting cultivators. At this point the deforestation process has already been set into motion whatever follows is a result of people reacting to economic opportunities created by a weak policy and enforcement milieu.

Secondly this work's analytical results have implication for global forest policy options the future of tropical forest stocks and the global public good characteristic of extant forest stocks. The current trend in mitigating global deforestation is to promote international programs treaties and agreements. This new policy environment differs significantly from past options which relied on the use of economic instruments to alter human behavior with respect to the tropical moist forest. Recognition of the importance of foreign assets to developing tropical

countries is essential to the success of the new policy strategy. Analytical results indicate that there exists an inverse relationship between foreign asset levels and the area industrially logged. Additionally, via deduction, foreign loans also demonstrate a similar inverse relationship. Consequently, negotiations which fail to identify alternative sources of foreign capital financing at minimum opportunity costs risk failure. As Sandler (1993) succinctly notes, the cake is shrinking as the world negotiates the fate of tropical moist forests.

The writing is on the wall. The recently deceased President of the Republic of Guyana, His Excellency Dr. Cheddi Jagan, spoke of the regrettable imminent tradeoff his government has to make in opening Guyana's forests to concessions in order to meet the country's need for foreign exchange (Jagan, 1996). Horta (1991) and Colchester (1994) write on the big rush for "Green Gold" and the colonization of Guyana's virgin Amazon forests. Reverberating throughout their writings is the prominence of foreign exchange needs to alleviate current economic crisis. If the deforestation fronts identified by Myers (1993) are to be arrested or contained, then the global community has to recognize the relationship between foreign capital availability and tropical deforestation.

The social value of forests and forest ecological systems depends crucially on the temporal and spatial dynamics of negotiations. These social values are inclusive of:

1) global public good characteristics such as the forest's role as storehouse for greater than half of the world's biodiversity, it's central role in

sequestering carbon--effectively mitigating the costly greenhouse effect and 2) local public good characteristics such as providing watershed protection erosion and flood control and protection against unknown diseases and wildlife extinction

The global economic consequences of forest stock loss cover increasing future health costs the costs of secondary disease intervention migration costs sundry agricultural costs associated with changing and unpredictable weather outcomes and the growing cognizance of the increasing costs of global warming This represents a short list however it portrays the magnitude of probable expenses the future could incur if the current tropical forest dilemma is not resolved

Future Direction

How much evidence is necessary for the recognition of foreign asset contribution to the tropical deforestation dilemma is not a scientific question but a local and global policy question Expanding the information matrix available to the local and global policy community can only fortify the creation of workable solutions

Therefore the most logical extension of the current research is an aggregation of the sample up to the regional and global levels The country specific analysis yields insights into local parameters shaping forest stock depletion patterns However if the policy community is to effectively address the deforestation dilemma regional assessments and global assessments are necessary conditions for successful policy formulation. Such assessments are

complicated by the different primary actors in forestry nationally and regionally However where there is a will there is usually a way

Central to extending the current work is finding a better proxy for the dependent variable forest area industrially logged It is calculated as the ratio of the volume of industrial wood removed (in 1000 cubic meters) and the average gross annual allowable cut (AAC) (in cubic meters per hectare) The denominator AAC is a weak measure since it is assumed constant throughout the study period 1967 - 1994 The advancement in and coverage of remote sensing technology is a probable solution to this problem since the instrument can yield direct measurement of lost forest areas due to industrial logging Proper coordination of technical experts and economic analysts is required to make effective use of the technological medium Time series analysis will not be possible with this data However cross sectional studies is another useful tool which can yield valuable insights into the relationship between the forest product trade financial variables, economics and the forest area industrially logged

A second extension of the work is the addition of a deforestation equation to the simultaneous system In this system the forest area industrially logged would remain an endogenous variable however it would be an explanatory variable in the deforestation equation This would yield greater insights into the relationship between the forest product trade and tropical deforestation by providing a direct link All studies to date the present work included have been able to make the forest-product-trade/deforestation relationship by deduction The possibility of

making direct association promises more robust estimates and more defensible recommendations Given the paucity of country level data such an extension is only possible at the regional or global levels where the possibility of panel analysis compensates for data limitations

APPENDIX A
FACTOR ANALYSIS DATA

Table A.1 Data Used to Create Variables for Factor Analysis

YEAR	%GGR	US-TE	US-IN	TED	GNP	TEXP	ND	INT-PMT	PR/NPMT	M-PI
1967	2 65	4 33	2 30	465 50	1897 60	303 00	9 80	4 75	7 48	26 50
1968	0 36	5 35	4 20	506 11	1815 54	332 00	39 48	12 85	21 21	25 50
1969	5 72	5 56	5 40	476 70	1912 88	327 00	40 39	13 48	16 74	28 50
1970	6 67	5 44	5 80	565 30	2168 64	458 00	41 80	12 10	14 10	26 50
1971	5 45	4 34	4 30	536 70	2383 82	356 00	37 80	15 20	13 10	25 90
1972	2 69	4 07	3 30	584 80	2087 30	418 00	41 50	6 80	7 40	30 60
1973	2 90	7 03	6 20	728 50	2447 11	629 00	32 20	12 00	11 10	38 60
1974	7 33	7 67	11 00	720 00	2874 97	732 00	31 00	13 00	14 00	54 10
1975	13 35	5 82	9 10	714 80	2787 67	609 00	31 00	18 90	35 00	57 10
1976	3 48	4 96	5 70	707 50	2744 96	632 00	44 80	18 30	33 50	58 20
1977	1 82	5 27	6 50	842 40	3178 06	1010 00	115 00	15 40	22 60	63 30
1978	6 83	7 22	7 60	811 80	3884 05	1050 00	113 10	23 60	44 20	70 40
1979	1 67	10 04	11 30	1078 20	4008 13	865 00	138 10	28 70	44 10	84 70
1980	0 58	11 62	13 50	1267 80	4426 35	1280 00	228 00	30 80	76 80	102 00
1981	-2 98	14 06	10 30	1252 70	4209 54	1060 03	114 70	38 40	38 80	100 00
1982	-8 48	10 72	6 20	1261 30	4025 48	974 00	86 40	29 60	41 70	86 80
1983	-4 45	8 62	3 20	1557 50	4021 12	503 00	152 00	43 80	98 40	92 80
1984	6 76	8 57	4 30	1704 40	4352 69	540 00	108 00	26 30	58 80	80 80
1985	5 08	7 48	3 80	2047 50	4428 58	617 00	181 60	29 80	64 80	90 80
1986	5 12	5 87	1 60	2553 30	5586 78	683 00	377 70	45 00	84 00	91 80
1987	4 84	5 33	3 70	3158 40	4830 62	677 00	387 20	55 80	110 30	100 00
1988	5 54	5 67	4 00	2897 80	5083 83	1010 00	401 10	71 20	141 60	104 10
1989	4 92	6 11	4 80	3126 80	5131 13	1020 00	384 00	61 80	154 80	107 10
1990	3 07	7 51	5 40	3478 30	5113 48	891 00	418 00	56 50	133 50	117 30
1991	5 20	5 41	4 20	3854 80	5878 15	888 00	449 30	62 80	108 40	114 30
1992	3 64	3 46	3 00	3987 80	6777 83	986 00	396 80	75 10	122 10	116 30
1993	4 80	3 32	3 00	4115 60	5862 18	1030 00	321 80	73 40	101 20	114 30
1994	3 59	4 96	2 60	4107 00	7853 85	1107 50	435 40	61 20	115 80	130 80

Table A.1--continued

%GGR Ghanaian percent GDP growth rate
US_TB US treasury bill rate
US_IN US inflation rate
TED Ghanaian total external debt (million $US)
GNP Ghanaian nominal gross national product (million $US)
TEXP Ghanaian total exports (million $US)
ND new debt disbursements to Ghana (million $US)
INT_PMT Ghanaian interest payments (million $US)
PRINPMT Ghanaian principal payments (million $US)
M_PI Ghanaian import price index (1987=100)

Table A.2-- Data Used in Factor Analysis

YEAR	PY	DR	IA	DSR
1967	1 1181	0 2742	11 3334	0 0405
1968	-0 7906	0 3133	13 2400	0 1020
1969	4 4300	0 2492	12 7241	0 0824
1970	9 1282	0 2610	17 9717	0 0572
1971	5 4093	0 2251	12 7832	0 0795
1972	-3 7520	0 2786	14 5817	0 0341
1973	2 0680	0 2983	18 4458	0 0387
1974	10 4625	0 2504	13 6044	0 0388
1975	10 0732	0 2564	13 7888	0 0685
1976	-2 7829	0 2577	14 1753	0 0623
1977	3 0536	0 2651	17 1722	0 0376
1978	10 2118	0 2486	18 1264	0 0622
1979	-0 4059	0 2681	12 5183	0 0742
1980	2 4402	0 2864	13 4559	0 0652
1981	-8 7170	0 2976	11 0550	0 0653
1982	11 0111	0 3133	9 2983	0 0616
1983	8 8660	0 3873	5 8844	0 2191
1984	3 4923	0 3919	9 1443	0 1631
1985	1 1818	0 4623	7 8656	0 1530
1986	1 0538	0 4570	12 1100	0 1495
1987	2 5064	0 6405	11 7810	0 1700
1988	2 8651	0 5920	11 5110	0 2107
1989	1 6052	0 6084	11 0568	0 2124
1990	9 9596	0 5630	9 5396	0 2132
1991	3 8864	0 5604	11 1645	0 1715
1992	3 1758	0 5751	10 1943	0 2000
1993	4 4778	0 6880	10 2892	0 1895
1994	1 2078	0 5228	10 2588	0 1780

PY Profitability [% GDP growth - US real interest rate]
DR Debt Ratio [total external debt / nominal gross national product]
IA Import Availability [(exports+new debt disbursements-(interest+principal payments) / import price index]
DSR Debt Service Ratio [(interest+principal payments) / total exports)]

APPENDIX B
DATA USED IN REGRESSIONS

Table B 1- Data for 3SLS Estimation

YEAR	HA	TC	IQ	ND	Y	GrY	M	FS	grf	ifs
1969	924 44	9109	1884	38 49	3680.24	-4.29	1207	0 23	18930	12050
1969	1067 78	9506	1922	40 39	4331 83	11.64	1308	0 35	23638	14884
1970	1046 97	9670	1920	41 90	4340 19	0 18	1549	0 97	19480	19749
1971	939 44	9941	1891	37 90	4124 98	-4 87	1537	-0.57	23300	11484
1972	1068 44	10159	1979	41.50	3987 84	-3 32	947	1.23	32141	16092
1973	1375 58	10897	2479	32.20	4733 72	18 71	1186	1.22	77039	36327
1974	1022 79	10491	1841	31 00	5010 17	5 84	1520	1 19	49002	28542
1975	846 89	10558	1708	31 00	4488 90	10 95	1404	-0 79	42719	24506
1976	1095 00	10895	1971	44 80	4051 30	9 30	1451	0 83	41265	23566
1977	1122 78	11179	2021	115 00	4513 09	11 40	1802	1 24	49890	18840
1978	939 44	10812	1511	113 10	4808 30	9 56	1405	0 87	38395	20467
1978	709 11	10733	1271	139 10	4731 77	1 61	1006	0.63	18573	20808
1980	545 00	10628	881	220 00	4908 56	3 70	1107	-0 48	12388	23212
1981	517.22	10983	931	114 70	4650 96	5 21	1110	-0 71	4381	11974
1982	439 44	11740	791	98 40	3983 82	14 34	727	-0.44	3469	6640
1983	530 56	13282	955	152.80	4060.26	1 92	564	1.61	4311	7888
1984	548.97	13372	984	106 06	4387 19	8 30	970	0 81	5140	10051
1985	583 33	13491	1010	191 80	4581 82	4 43	905	0 86	9550	14077
1986	594.44	13499	1079	377 70	4819.29	4 98	853	0 53	18440	18000
1987	588 97	13552	1020	387 20	4930 82	2 38	888	0 90	39508	43836
1988	538 98	13720	870	401 10	5203 64	5 53	870	1 48	45420	45365
1989	511 11	13780	820	384 00	5302 14	1 89	1185	1 50	23808	43670
1990	900 00	14310	1440	418 00	5423 49	2 29	1023	1 53	33888	84053
1991	766 11	12378	1379	449 30	5726 52	5 58	1155	0 90	42013	51285
1992	722 22	19300	1300	396 80	5849 38	2 09	1255	1 33	40808	98782
1993	1017 78	19332	1932	321 80	5898 93	2 83	1488	0 93	58719	72677
1994	1083.33	22928	1950	435 40	6326.82	5.45	1482	0 93	73205	130887

Table B.1--continued

YEAR	qrv	qrp	qpr	qps	qpv	qpp	FA	RXR	QX	VQX
1968	19	3380	2 87	5 80	18 00	42 75	57 00	175 51	782 50	100 01
1969	145	2602	3 39	6 69	26 00	13 77	71 83	168 94	835 50	120 38
1970	78	2080	4 13	8 85	16 50	13 73	42 58	170 91	735 00	109 85
1971	222	1724	4 21	8 15	11 10	13 80	43 08	163 47	754 20	97 07
1972	840	2222	4 30	9 43	17 30	13 31	104 04	169 81	1017 70	126 08
1973	845	9827	8 00	11 91	15 73	21 17	194 04	187 94	1212 00	285 44
1974	1705	3869	11 29	17 48	18 41	23 74	101 33	196 63	628 10	184 61
1975	1444	5951	8 71	14 85	18 25	33,62	147 19	140 22	930 20	145 53
1976	480	5587	11 68	16 85	23 00	32 87	113 30	94 01	503 30	132 89
1977	1372	659	10 84	25 77	24 95	34 68	181 58	46 10	534 80	124 87
1978	2145	773	12 28	28 51	27 50	42 84	328 68	44 02	399 20	101 50
1979	2331	581	9 38	28 43	42 35	32,28	401 24	50 01	283 30	69 39
1980	2935	395	11 82	33 45	38 13	26 33	328 58	38 03	183 30	53 87
1981	2161	44	8 12	22 54	30 44	44 00	268 43	18 17	114 20	23 36
1982	1024	51	6 52	18 77	18 32	17 00	314 34	15 99	98 40	13,25
1983	1678	269	7 00	18 04	19 08	28 99	291 31	23 33	113 80	15 87
1984	2534	59	7 34	17 82	22 03	28 50	437 21	69 70	136 10	18 48
1985	2955	105	7 35	17 53	21 31	11 97	552 95	95 00	224 50	28 19
1986	3000	62	10 44	17 80	19,63	11 71	623 87	121 52	285 80	40 78
1987	7544	961	12,40	25,24	39 42	46,30	331 85	153 73	514,20	91 34
1988	8870	910	13 40	26 75	41 72	40,87	318 35	160 23	530,80	98 35
1989	9788	302	11 85	26 36	39 85	30,20	435 93	179 20	371 00	70 88
1990	11187	575	24 14	31,95	94 88	30,28	309 31	193 42	358 95	87 19
1991	12438	585	22 88	27 71	94 11	42 50	844 30	158 41	389 58	91 06
1992	18273	417	24 25	43 43	105 70	80 50	411 56	184 83	387 29	123 22
1993	15447	1210	11 44	30 38	91 54	43 21	516 97	204 83	762 75	118 76
1994	24037	581	17 30	48,37	108,83	53 67	559 27	244 55	717 55	180 08

Table B.1--continued

YEAR	WI	PW	wtr	wfs	wtv	wtp	wtr	wps	wav	wpp
1966	6791 20	23 80	753487	403880	195556	538588	2 50	6 00	22 46	12 85
1969	7147 90	24 70	861496	457065	216763	613313	2 48	6 26	24 35	13 51
1970	7418 82	26 00	893447	499204	220320	649864	2 31	6 39	25 45	13 67
1971	7681 98	27 60	958074	492487	235881	732121	2 37	8 40	21 82	13 81
1972	8048 44	30 10	1089261	605248	304305	953545	2 56	7 65	23 36	15 89
1973	9585 85	38 50	2063846	1148464	443173	1403016	3 65	10 38	33 21	21 19
1974	9544 42	45 60	2175111	1241362	428877	1262720	4 65	13 00	32 52	24 96
1975	8627 33	50 50	1420987	1078785	381034	1205656	3 92	12 60	30 47	22 38
1976	8002 16	50 20	2285202	1558239	439983	1617243	5 04	13 30	37 88	25 28
1977	8371 31	54 30	2521582	1747827	461182	1794375	5 38	15 05	39 58	27 62
1978	8754 33	61 80	2769442	2020787	511019	2100695	5 73	19 26	39 76	28 28
1979	10086 72	71 20	4273067	2947872	763047	2615050	8 29	21 14	58 54	37 47
1980	10214 28	80 50	4424552	3172803	880410	2706856	10 80	24 05	61 76	40 55
1981	10407 37	77 00	2934482	2480867	718824	2765065	8 86	21 74	51 17	37 90
1982	10410 58	74 10	2694513	2350156	653730	2405417	8 67	20 70	50 62	35 06
1983	10583 71	71 60	2753492	2711780	793134	2637108	8 50	21 09	38 34	33 62
1984	11102 84	69 40	2137840	2572317	808340	2468326	7 20	18 77	40 32	30 60
1985	11385 52	99 00	2068484	2366608	740896	2761167	6 99	18 35	41 59	31 55
1986	11868 25	78 00	2141986	2834604	783509	3033431	7 44	22 36	42 55	30 47
1987	12253 40	85 40	2852461	3566273	847696	4258107	8 64	23 37	48 36	35 80
1988	12546 66	61 50	3028462	4247884	1111432	4630676	8 13	23 88	61 21	37 23
1989	13282 56	91 80	3175522	4809535	1156987	5522846	8 39	27 51	70 41	38 52
1990	13582 56	100 00	4083870	4607845	1346469	5783911	10 15	30 27	63 03	37 06
1991	13703 48	99 00	3878898	4784111	1257484	6008106	9 28	31 50	65 45	39 12
1992	13907 92	101 70	4424866	5838229	1537822	6440212	10 53	33 69	63 84	36 09
1993	14101 72	96 40	3894035	5180115	1537332	6009240	13 59	36 87	65 76	45 63
1994	14400 95	99 70	4175890	6371621	1778450	8031698	13 13	39 98	79 20	45 37

Table B.1--continued
HA forest area industrially logged (1000 hectares)
TQ total volume of forest products produced (1000 cubic meters roundwood equivalent)
IQ total industrial volumed removed (1000 cubic meters roundwood equivalent)
ND new debt disbursement (million $US)
Y real gross national income (million $US 1987=100)
GrY growth rate of real gross national income
M real total imports (million $US 1987=100)
FS index of financial distress
grr Ghana roundwood export revenue (million $US)
grs Ghana sawnwood export revenue (million $US)
grv Ghana veneer sheet export revenue (million $US)
grp Ghana plywood export revenue (million $US)
gpr Ghana roundwood export price (Unit Value)
gps Ghana sawnwood export price (Unit Value)
gpv Ghana veneer sheet export price (Unit Value)
gpp Ghana plywood export price (Unit Value)
FA total foreign reserves (million $US)
RXR real exchange rate (cedi/$US)
QX total volume of forest products exported (1000 cubic meters roundwood equivalent)
VQX real value total forest product exports (million $US 1987 = 100)
W real OECD income (billion $US)
PW world price index (1990=100)
wrr OECD roundwood export revenue (billion $US)
wrs OECD sawnwood export revenue (billion $US)
wrv OECD veneer sheet export revenue (billion $US)
wrp OECD plywood export revenue (billion $US)
wpr OECD roundwood export price (Unit Value)
wps OECD sawnwood export price (Unit Value)
wpv OECD veneer sheet export price (Unit Value)
wpp OECD plywood export price (Unit Value)

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Trevor Woollery is a Jamaican born May 3 1969 He spent the first fourteen years of his life in Jamaica where he attended Alpha Primary School (later to be called Jessie Ripoll Primary School) and Wolmer's High School for Boys He migrated to the United States in 1983 He enrolled at Dewitt Clinton High School (Bronx New York) and completed his high school diploma in 1986 Trevor competed successfully in sports particularly track and field He demonstrated talent in the 400 meter and 800 meter track events He was captain of the track and field team at Dewitt Clinton (2 years)

The author earned his B S in Geography degree (1990) from Colgate University (Hamilton New York) and M S degree in food and resource economics (1994) from the University of Florida At Colgate University he was the recipient of the Shannon McCune Prize awarded to the senior demonstrating outstanding academic merit in geography Also, he was captain of the Colgate men s indoor and outdoor track and field teams while competing in the 400 meter and 800 meter track events At the University of Florida his Ph D qualifying examination was graded as an outstanding pass

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate in scope and quality as a dissertation for the degree of Doctor of Philosophy

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